SCIENTIFIC AMERICAN
HANDY BOOK OF FACTS AND FORMULAE

SCIENTIFIC AMERICAN SERIES

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HANDY BOOK
OF
FACTS AND FORMULAE

Edited by

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PREFACE

WHEN a receipt or a table of weights and measures is wanted in a hurry there is generally a trip to a library and a search through old or indifferent authorities before the matter desired is secured. Each year the "Scientific American" receives 15,000 letters of inquiry and the query editor with a staff of four highly trained specialists, Engineers, Electricians, Chemists and all-around technicians deal with this enormous mass of correspondence. The reading of this vast number of letters shows what people really want to know. Very generally the inquiries are inspired by a desire to improve themselves in their trade or profession, a most laudable desire, and assistance is freely afforded. It is on the basis of actual knowledge of what over 200,000 men really want that the present volume has been compiled largely from the successes which are the literary property of the publishers. Years of effort and considerable sums of money have been spent in securing the information which is now presented in a form which is so usable and portable that even the enormous sales of the "Scientific American Reference Book" and the "Scientific American Cyclopedia of Formulas" will be eclipsed. It is hoped that the usefulness of this little volume will obtain in the shop, the amateur's workshop and the home. It is essentially a book for men but if its success warrants it, possibly a book of "Household" formulas may follow in due time.

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PART I.

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CHAPTER I.

MECHANICAL MOVEMENTS

TOOTHED GEAR.

1. Spur Gears.—The ordinary form of toothed-wheel. The smaller of two intermeshing gear-wheels whether a spur- or bevel-wheel is called a Pinion.

2. Gear with Mortised Teeth.—This is what is ordinarily known as a Cog-wheel among machinists. The wheel is ordinarily made of iron and the teeth of wood.

3. Step Gear.—The face of this gear is divided into sections with the teeth of the different sections arranged in steps; that is, one in advance of the other. Step gear-wheels are useful in heavy machinery, as they give a practically continuous bearing between the intermeshing teeth of the gear-wheels.

4. Oblique Toothed Gear.—The teeth are cut diagonally across the working face of the wheel so as to give the gear-wheel a side thrust. In a double oblique toothed-gear, usually called a V-toothed gear, the thrust in one direction is neutralized by an equal thrust in the opposite direction. As in the stepped-gear it gives a continuous bearing of the teeth.

5. Internal or Annular Gear.—The teeth are formed on the inner periphery of a ring. This type of gear is used in heavy machinery, because it offers a greater hold for the teeth of the driving pinion. There is less sliding friction between the teeth than in the usual outside spur-gear and pinion.

6. Star Wheel Gears.—The teeth are so formed as to permit an appreciable separation of the gear-wheels without preventing them from properly meshing one with the other. These gears are used on wringing machines, etc.

7. Elliptical Gears.—Due to their elliptical form, while the driving-gear rotates at constant speed, the other gear will be rotated at a variable speed. That is, its motion will first be accelerated and then retarded. They are used in some machines to produce a slow powerful stroke followed by a quick return.

8. Angular Gears.—These gears have a rectangular form and, as in the elliptical gears, they serve to transform uniform rotary movement into variable rotary movement. However, this movement is more jerky than that produced by elliptical gears. Angular gears are very seldom used.

9. Lantern Gear.—The teeth consist of pins which lie parallel with the axis of the gear-wheel, and are secured at their ends in two disks or gear heads. The pins are so spaced as to mesh with the teeth of a spur-gear. The lantern-gear permits limited sliding movement of the spur-gear along its axis. It can be very cheaply made, but is used chiefly for light work, such as clock mechanism, etc.

10. Crown Gear.—The teeth project perpendicularly from a side face of the wheel instead of lying in the plane of the wheel. When in mesh with the teeth of a spur-gear or a lantern-gear, it forms a cheap method of transmitting power from one shaft to another lying at right angles thereto. Crown gears are useful for light work, and were common in old clock mechanisms. They used to be known as *Contrate* wheels.

11. Bevel Gears.—The ordinary gear for transmitting power from one shaft to another at an angle thereto. When the wheels are of the same size and operate on shafts, lying at an angle of 45 degrees, one with the other, they are called Miter gears.

12. Worm or Screw Gear.—An endless screw engages a spur-gear with spirally disposed teeth. The screw is called a worm, and the spur-gear a worm-wheel. A much diminished but very powerful motion is communicated from the worm to the worm-wheel. It is used in heavy machinery.

13. Curved Worm Gear.—The working face of the worm is curved so that a number of teeth will be in mesh with the worm-wheel, thus giving greater strength. It is a difficult matter to cut the thread of this worm correctly owing to its varying pitch. The gear is called the saw-tooth gear when the teeth and thread are V-shaped, as illustrated.

14. Spiral or Helical Gears.—The teeth are spirally disposed on the working faces of the wheels so that they will transmit motion to shafts lying at right angles one with the other.

15. Skew Gears.—The gears rotate on shafts which lie in different planes and at an angle with each other. The drawing shows a skew spur-gear meshing with a bevel-gear. The same term would apply to two bevel gears lying in different planes and at angles to each other.

16. Rack and Pinion.—A spur-gear engages a toothed bar. Rectilinear motion is by this mechanism transformed to rotary motion or vice versa. It is quite common in heavy machinery to find a worm meshing with and driving a rack.

17. Spherical or Globoid Gear. — A spiral thread is cut on a spherical body and meshes with the spiral teeth of the spur pinion. The latter is so mounted that it may be swung to different positions on the spherical gear, thus varying its speed of rotation.

18. Gear with Roller Teeth.—The teeth project from the flat face of the wheel, and consist of pins carrying rollers. This construction is used to reduce friction.

19. Pin Wheel.—The flat face of the gear is studded with pins which are adapted to

mesh with slots formed in the edge of a pinion. The pinion is so mounted that it can be moved toward or from the center of the pin wheel to vary its speed of rotation. When the pinion is moved past the center of the pin wheel its direction of rotation is reversed.

20. SPIRAL HOOP GEAR.—A spiral thread is formed on the flat face of the wheel and this meshes with a worm-wheel. The latter is moved forward one tooth at each complete rotation of the spiral hoop. This gives a powerful drive, though, of course, at a greatly diminished speed.

21. INTERMITTENT GEAR OR GENEVA STOP.—The driving-wheel is provided with a single tooth adapted to engage one of a series of notches in the other wheel. At each complete rotation of the driving-wheel the other wheel is moved forward one notch but no more, due to the concave space between the notches which fits closely against the circumference of the other wheel. In the Geneva stop one of these spaces is formed with a convex outline, as illustrated. When this space is reached both wheels are prevented from further rotation forward. The Geneva stop is used on watches to prevent winding up the main spring too tightly.

22. INTERMITTENT BEVEL GEAR OR MUTILATED GEAR.—The teeth are formed only at intervals on the face of the gears. The space between the teeth in the driving-gear is convex, and that between the teeth in the other gear is concave, so that when the teeth are not in mesh with each other these convex and concave portions fit into each other and prevent the driven gear from moving forward under its own momentum.

23. VARIABLE GEARS.—The gear wheels are made up of gear sectors of different radial length, which produce suddenly varying motions of the driven gear due to the varying leverage between the wheels. The segments are arranged on different planes so as not to interfere one with the other.

24. SCROLL GEARS.—The gears have a scroll form which produces a gradually increasing or decreasing speed during each rotation. These gears are also called cam gears.

25. ELLIPTICAL BEVEL GEARS.—They produce variable motion of a shaft lying at right angles to the driving shaft. This gear is used on bicycles to give increased power on the downstroke of the pedal and a quick movement on the return.

26. VARIABLE PIN WHEEL.—A cone is provided with pins arranged spirally thereon, and these mesh with teeth formed on the other cone. When one cone is rotated at a constant speed the other moves with a gradually increasing or decreasing speed during each rotation.

27. CAM-TOOTHED PINION.—The pinion consists of two oppositely disposed heart-shaped teeth, mounted side by side, on a shaft. The gear-wheel with which they mesh has teeth alternately arranged on opposite side faces. Due to the form of the pinion teeth, the gear-wheel is locked after being moved forward by one tooth until the other tooth comes into mesh with a tooth on the other face of the wheel.

28. BEVEL SCROLL GEAR.—The gear-wheel consists of a bevel spiral scroll which meshes with a bevel pinion. As the spiral scroll rotates it causes the pinion to slide forward on its shaft, and thus varies its speed.

FRICTION GEAR.

29. FLAT-FACED FRICTION GEAR.—A common type of friction gear. The wheels are usually faced with rubber or leather to increase the frictional hold between the wheels. One of the wheels is journaled in bearings which can be adjusted toward the other wheel so as to increase the frictional engagement.

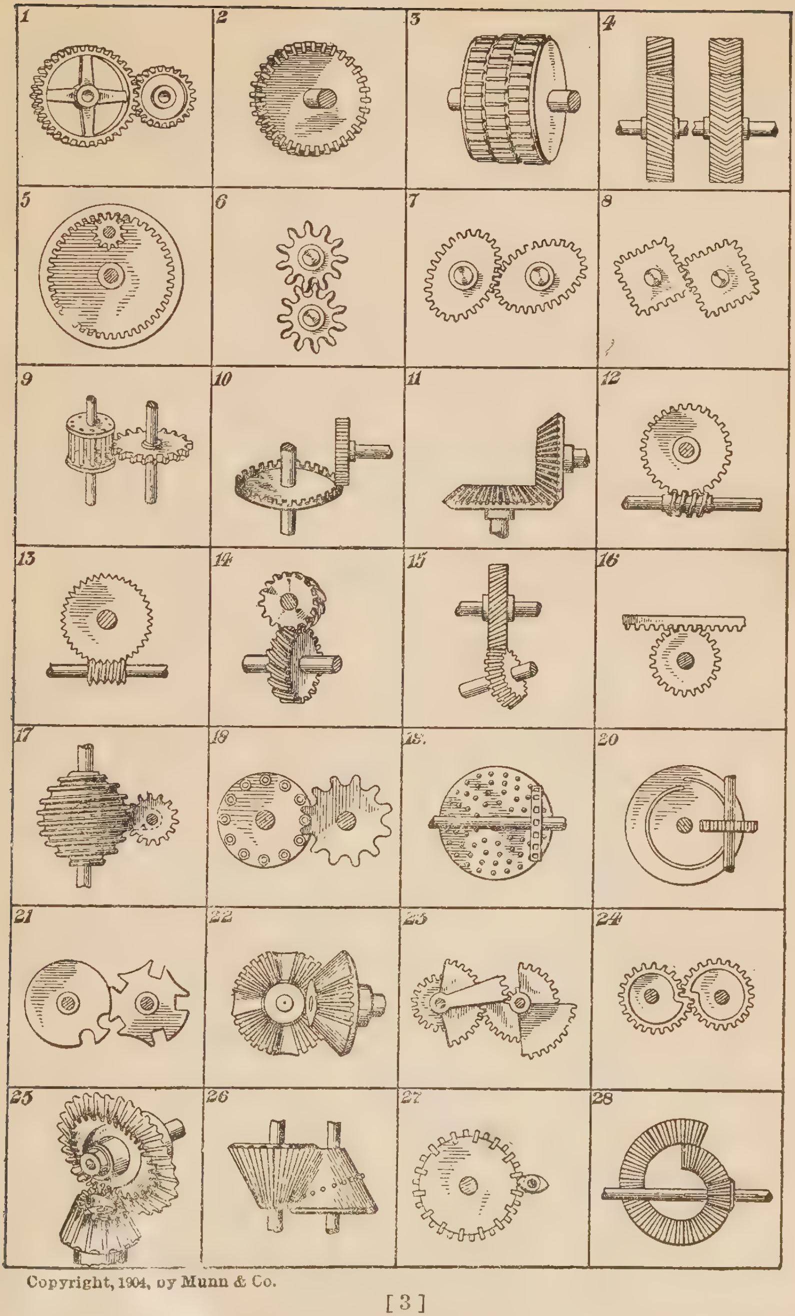
30. GROOVED FRICTION GEAR.—The faces of the wheels are grooved so as to increase the bearing surface. The best results are obtained by pressing the wheels but slightly into engagement with each other, as this produces little loss of power by friction.

31. ADJUSTABLE FRICTION PINION.—The pinion is formed of a disk of rubber or other flexible material held between two washers. When these washers are tightened together they press out the rubber between them, crowding it into closer contact with the V-groove of the gear with which it engages.

32. BEVELED FRICTION GEAR.—Two cone frustums are used to convey motion from one shaft to another at right angles thereto.

33. FRICTION DRUMS.—The drums have concave faces which permit them to transmit motion one to the other while lying at an acute angle with each other.

34 to 40. VARIABLE SPEED FRICTION GEAR.—34, a pinion, engages the flat face of the friction disk. Variable motion is produced by moving the pinion across the face of the disk. When the center of the disk is reached no motion is transmitted. Beyond the center the direction of motion transmitted is reversed. 35. Motion is transmitted from one friction disk to another lying parallel, but not in alignment therewith, through an intermediary pinion. This pinion can be moved vertically to engage different points on the friction disks, and thus produce any desired variation in the speed transmitted. 36. Two convex friction disks are so arranged that one may be swung through an angle bringing different points on its surface into contact with the face of the other disk. In this manner the speed of the motion transmitted is varied. This gear is used on sewing-machines. 37. Two parallel friction disks are each provided with an annular concavity. Motion is transmitted from one disk to the other by a friction pinion mounted between the disks, and so arranged that it can be rotated to engage different points on the surfaces of the concavities, thereby varying the speed transmitted. 38. A cone with concave face is engaged by a pinion which may be swung about a center to engage different points on the face of the cone. 39. Two cones with concave faces are mounted on shafts running at right angles to each other. Motion is transmitted from one cone to the other through a friction pinion mounted to swivel so as to engage different points on the faces of the cones. 40. Two friction cones are mounted on parallel shafts, and between them runs a friction pinion having two faces, one engaging the upper cone and the other engaging the lower cone. This provides a broad bearing surface. The pinion may be moved to different positions along the faces of the cones, and thereby produce changes in the speed.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41. Sprocket Wheel.—The wheel is provided with teeth adapted to fit in between the links of a chain. The chain may be of the ordinary oval welded link type or of the flat riveted type used on bicycles.

42. Link-belt Wheel.—The chain is made up of square links which are engaged by ratchet-shaped teeth on the chain wheel.

43. Pocket Wheel.—The wheel is formed with pockets into which the links of the chain are adapted to fit.

44. Side-toothed Wheel.—The wheel is formed with two sets of teeth between which the chain travels. The teeth bear against the ends of the outer links of the chain.

45. Side and Center Toothed Chain Wheel.—This wheel is similar to that shown in Fig. 44, but has in addition a row of teeth along the center which bear against the center link of the chain.

46. Toothed-link Chain and Wheel.—The links are formed with projecting teeth which fit into notches on the rim of the chain wheel.

47. "Silent" Chain and Wheel.—This is a special type of chain in which each link is formed with a tooth at each end. The teeth of adjacent links coact to completely fill the spaces between the teeth of the chain wheel. The construction is such as to produce a noiseless operation of the chain gear even at high speeds.

48. Detachable Toothed-link Belt and Wheel.—Each link is formed with a tooth, which meshes with the teeth of the chain wheel. The construction of each link is such that it may be readily slipped into or out of engagement with the next link of the chain.

ROPE GEAR.

49. V-Pulley.—The ordinary type of pulley for round ropes or cables. Owing to the V-shaped construction of the pulley groove, the rope wedges tightly into engagement with the pulley.

50. Pulley with Flexible Filling.—In order to secure frictional engagement of the cable with this pulley, the pulley groove is provided with rubber, leather, wooden, or other filling.

51. Pulley with Ribbed Groove.—In this construction of pulley the required grip is produced by forming ribs in the bottom of a pulley groove.

52. Pulley with Gripping Lugs.—The flanges of this pulley are formed with lugs which kink the rope or cable as shown, thus producing the required grip.

53. Rope Sprocket-wheel.—An old form of rope gear used in hoists and the like.

54 and 55. Gripping Pulleys.—Gripping arms are provided which grip the cable at the point where the cable presses into the pulley. In 54 the gripping arms are wedged inward by the side walls of the pulley groove when pressed downward by the cable. These arms are normally h ld up by coil springs. In 55 the cable is gripped by the toggle movement of hinged clips placed at intervals along the periphery of the pulley.

56. Cable Sprocket-wheel.—The cable is provided with clamps which enter sockets formed in the cable wheel. This is a form of cable gear commonly used at present in elevating and conveying machinery.

CLUTCHES.

57. Common Jaw Clutch.—One member of the clutch is mounted to slide on a feathered shaft, and the other member which is connected with the machinery is normally stationary on this shaft. When the slidable member is moved forward the teeth on its forward edge intermesh with the teeth of the other member, setting the machinery in motion. The slidable member is moved forward by means of a forked lever which is hinged to a split collar mounted loosely between flanges on the clutch member.

58. Claw Clutch.—The slidable member of the clutch consists of a body portion with two claw arms which, when moved forward, are adapted to engage opposite sides of a bar on the other member of the clutch.

59. Lever Clutch.—The slidable member is provided with a lever loosely hinged to its forward end. The other member of the clutch consists of a disk formed with ratchet teeth on its face. These are engaged by the hinged arm when the shaft rotates in one direction, but the arm moves freely over them when rotated in the opposite direction.

60. Knee and Rose Clutch.—A crank arm is attached to the slidable member of the clutch, and engages a pin on an arm loosely hinged to the opposite member of the clutch.

61. Ratchet Clutch.—The clutch members are formed with ratchet teeth, so that when the motion of the driving shaft is reversed, the members will be disengaged.

62. Pin Clutch.—The slidable member is provided with radial arms formed with pins at their outer ends which are adapted to enter sockets formed along the periphery of a disk on the opposite member of the clutch.

63. Friction Disk Clutch.—The two clutch members are each formed with disks preferably faced with rubber or leather, so that when pressed together their frictional engagement will cause a transmission of motion from the rotating disk to the other.

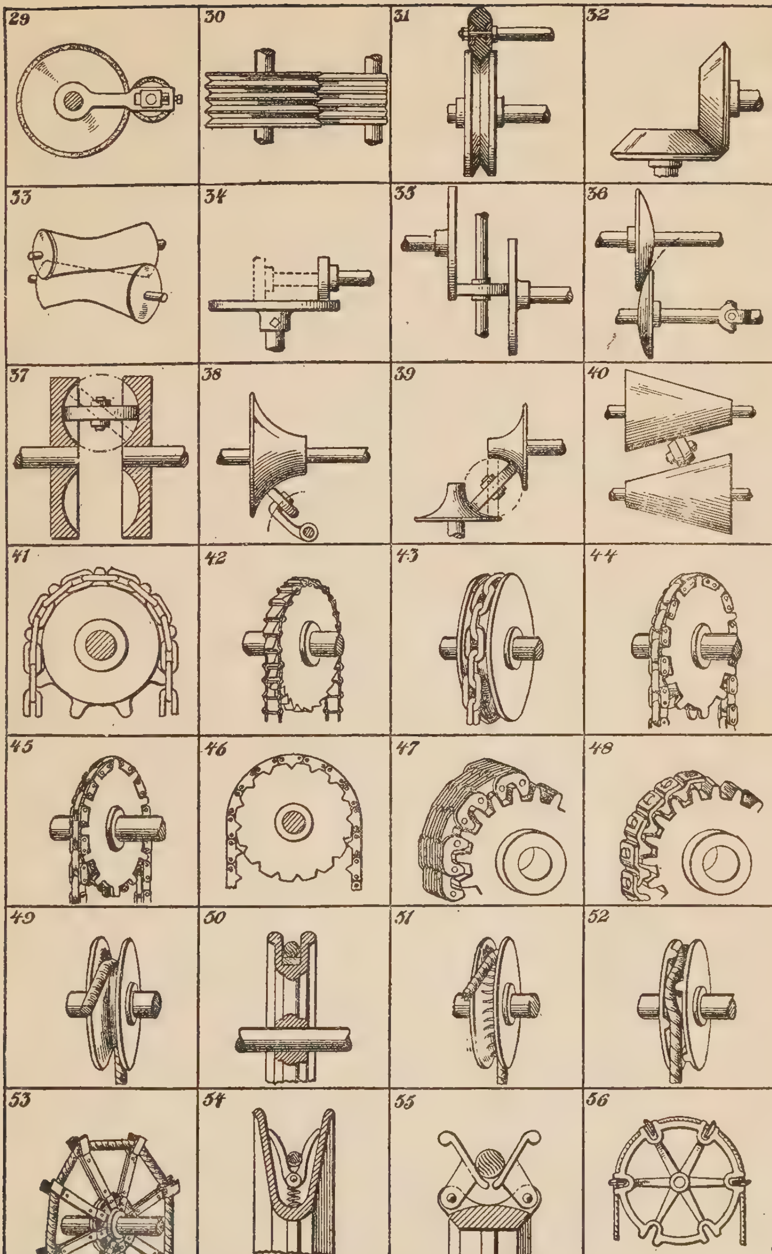
64. Friction Groove Clutch.—One of the clutch members is formed with a groove in its face to receive the lip of the other member which is cup-shaped. Both the lip and the side walls of the groove are slightly tapered to insure a close fit, even after the parts have been partly worn away by friction.

65. Stud Clutch.—Engagement between the two members of the clutch is effected by means of a stud on each disk adapted to enter a notch formed in the periphery of the opposing disk.

66. Friction Band Clutch.—One member of the clutch consists of a pulley provided with a steel band which encircles and fits tightly on its periphery. The other member of the clutch consists of a lever provided with pins at its outer ends, which are adapted to engage the steel band. Since this band is not fastened to the pulley, any shock due to suddenly throwing the clutch members into engagement will be taken up by the steel band slipping on the face of the pulley.

67. Friction Cone Clutch.—The clutch is made up of two cones, one adapted to fit into the other. The frictional engagement causes one to drive the other.

68. Self-releasing Clutch.—The clutch disks are provided with inclined teeth, so that in case the resistance to the driven shaft in-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creases beyond a certain degree, the clutch members will automatically move apart.

69. Cam Clutch.—One of the members is cup shaped, and within this the other member operates. The latter comprises a number of cam-shaped arms hinged to a body portion, and so arranged that when moved in one direction they will bind against the inner wall of the drum, but when moved in the opposite direction they will be automatically disengaged therefrom.

70. V-grooved Clutch.—The clutch disks are formed with annular V-grooves adapted to fit into each other, and thus increase the friction surface of the clutch members.

71. Expansion Clutch.—The slidable member is provided with a number of movable ring segments connected by radial arms to the main body of the clutch and adapted to bear against the inner surface of the drum or cup which constitutes the other member of the clutch. When the slidable member is moved forward, by reason of the toggle action of the radial arms, the segments are brought into frictional engagement with the other member of the clutch.

72. Coil-grip Clutch.—The movable member of the clutch is formed with a number of coils of steel in which there is a central conical opening. This is moved over the cone which constitutes the opposite member of the clutch, producing the required frictional engagement of the two members.

ANGLE SHAFT COUPLINGS AND UNIVERSAL JOINTS.

73. Crank and Hinged-pin Coupling.—A coupling for shafts which lie at an angle to each other. One shaft carries a hinged pin which fits into an opening in the outer end of a crank arm carried by the other shaft.

74. Double-sleeve Angle Coupling.—Each shaft carries a crank arm provided with a pin at its outer end, which lies parallel with its respective shaft. The two pins enter a coupling device consisting of two sleeves integrally formed, but lying at an angle with each other which corresponds to the angle formed by the shafts. Through this double-sleeve coupling, motion is transmitted from one shaft to the other, the pins sliding back and forth in the sleeve openings.

75. Cross-bar Angle Coupling.—This is used for coupling two parallel but offset shafts. Each shaft carries a yoke piece provided with sleeves at its outer ends. The coupling member is a cross-shaped piece, its arms fitting into the sleeves of the yoke pieces, and permitting the necessary lateral play as the shaft rotates. This form of coupling is also applicable to shafts which lie at an angle with each other.

76. Pin and Slot Coupling.—A crank pin carried by one shaft engages a slot in a crank arm carried by the other shaft. The motion transmitted is variable, due to the fact that the leverage varies as the pin moves up and down in the slot.

77. Ring-Gimbal Universal Joint.—The ends of the shafts are provided with yoke members whose arms are pivoted to a ring-gimbal, the pivot pins of the two yoke pieces lying at right angles to each other. This coupling will communicate motion at any angle under 45 degs. For angles of over 45 degs a double-link universal joint is used.

78. Double-link Universal Joint.—A link forked at each end is hinged to two rings, which are mounted in the yoke pieces on the ends of the shafts. In place of rings cross pieces such as shown in the illustration are often used.

79. Hooke's Angular Coupling.—The shafts are connected by two double links which are arranged in the form of a parallelogram. Intermediate of the shafts the links are connected with ball-and-socket joints

80. Ball-and-socket Universal Joint.—Socket pieces are secured to the ends of the shafts, and these are provided with metal bands which encircle the ball that constitutes the coupling member. The bands enter grooves in the ball which lie at right angles to each other.

81. "Almond" Angular Coupling.—A side view of the coupling is shown at 1 and a plan view at 2. Between the shafts to be coupled is a fixed stud on which a bell crank is mounted to turn. The bell crank is permitted to slide axially on the stud. The bell crank is connected at the ends by ball-and-socket joints with links attached to the ends of the shafts. Now, as the power shaft rotates, rotary motion will be communicated to the other shaft through the bell crank, which will rock and also slide axially on the stud.

82. Flexible Shaft.—Two shafts are connected by a flexible shaft consisting of a coil spring, or a metal tube in which a helical saw-slot has been cut. This flexible shaft will permit transmission of motion through a wide angular range.

83. Linked Flexible Shaft.—The flexible shaft is made up of a series of links coupled together with universal joints. A coil spring fits loosely over the links and prevents them from kinking. This spring in turn is covered with a flexible tube. The shaft will transmit motion about almost any curve or angle. It can be used for heavy work.

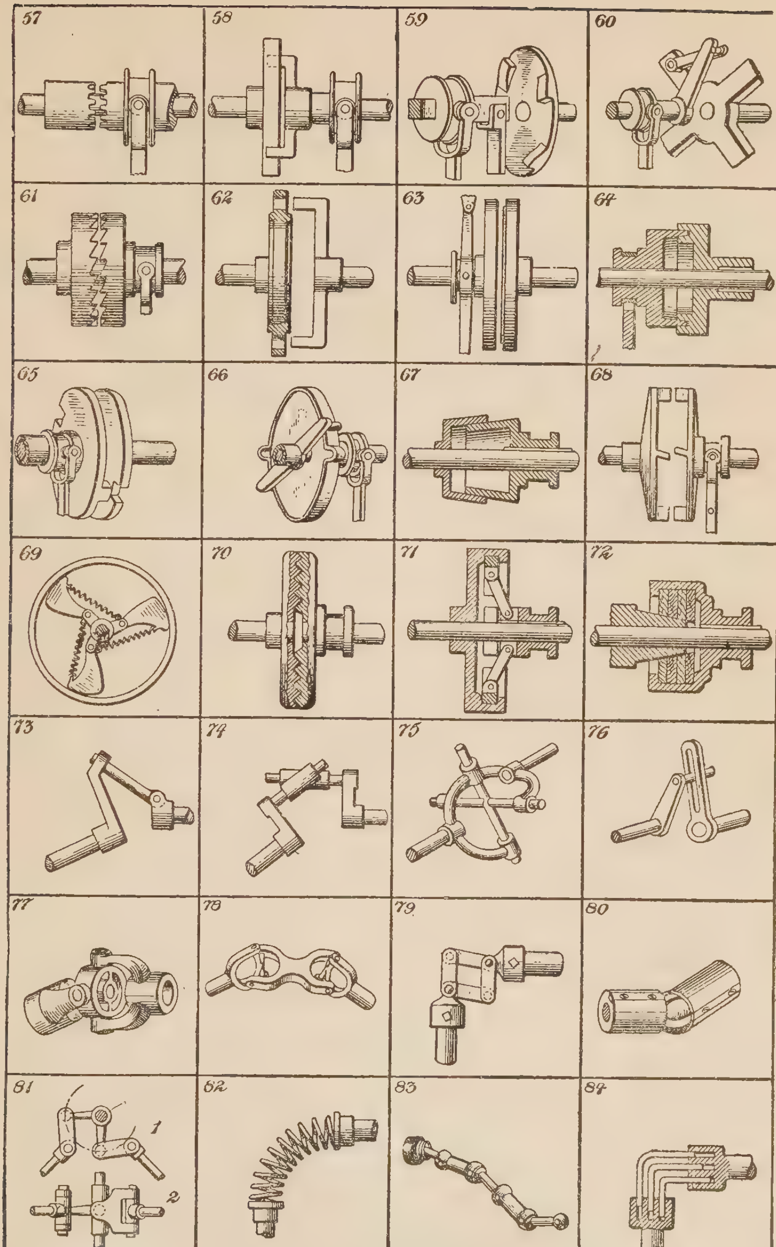
84. Right-angle Coupling.—The ends of the shafts are formed with heads in which are drilled a number of sockets. A series of rods each bent to form a right angle, enter these slots and form the coupling links between the shafts. As the shafts rotate these rods slide in and out of their sockets.

RATCHET MOVEMENTS.

85. The teeth of a ratchet wheel are engaged by a pawl hinged to a rocking arm. The ratchet wheel is rotated only on the forward stroke of the arm.

86. A rocking lever carries two pawls, one on each side of its fulcrum. The wheel is rotated both by the downward and the return stroke of the lever; for while one pawl is rotating the wheel, the other swings to position to take a new hold on the ratchet wheel. The rotation of the ratchet wheel is thus kept nearly constant.

87. A ratchet crown-wheel or rag-wheel is engaged by pawls depending from two arms loosely pivoted on the axle of the ratchet-wheel. These two arms are connected by links to a common power arm. Rectilinear reciprocating movement of the latter in the line of the arrow produces an almost constant rotation of the ratchet-wheel.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88. The action of this ratchet mechanism is very similar to that shown in Fig. 86, except that the pawls are hooked and ratchet-wheel is rotated by an alternating pulling rather than pushing action of the pawls.

89. This is a modification of the principle pictured in Fig. 88, and shows a rocking lever with two pawls hinged thereon engaging a ratchet rack.

90. Another modification of the principle shown in 88. The rocking lever is mounted on a fixed stud and is provided at the center with a pin which enters a slot in a ratchet bar. The latter is formed with ratchet teeth on its opposite edges which are engaged by hooked pawls pivoted on the rocking lever. These pawls are crossed, as shown, so that they will be kept by gravity in constant engagement with the ratchet teeth. Now, when the lever is rocked the pawls will alternately act to lift the ratchet bar.

91. A common construction used for rotating a ratchet-wheel against a spring resistance. A dog mounted on a fixed pivot drops by gravity or by spring pressure against the ratchet teeth and holds the wheel from turning while the pawl is being swung back for a fresh hold on the ratchet-wheel.

92. This shows the method of rotating an ordinary spur gear-wheel by means of a pawl. The pawl is provided with a tooth at its outer end which fits between the teeth of the gear. The pawl is hinged to the lower arm of the bell-crank lever mounted on the gear shaft. The operating lever also mounted on this shaft is permitted a certain amount of play between two pins on the shorter arm of the bell crank-lever. A rod connects the operating lever with the pawl. When the lever is raised it first lifts the pawl out of engagement with the gear, then, coming in contact with the upper pin on the bell crank-lever, it moves the pawl and bell crank back to the desired position. On lowering the operating lever the pawl is first brought into engagement with the gear and then the lower pin on the bell crank is encountered, and the gear is caused to rotate. This arrangement prevents wearing away of the teeth—a common defect in the ordinary type of ratchet mechanism.

93. The pawl is kept in contact with the ratchet-wheel by the weight of the lever on which it is formed. By pulling the rope attached to the end of the lever the pawl will be drawn out of engagement with the ratchet-wheel, and the latter will be turned by friction of the rope on the wheel hub.

94. A reversible spur-gear ratchet mechanism. Mounted on the shaft which carries the spur-gear is a bell crank-lever. This at one end carries a double-toothed pawl, one of which teeth meshes with the teeth of the gear. The pawl is so shaped that it will withdraw the tooth from engagement with the gear teeth on the return stroke of the lever. When it is desired to reverse the direction of rotation, the pawl is moved over to the position shown in dotted lines, bringing its other tooth into engagement with the gear teeth.

95. The ratchet-wheel is intermittently rotated by the oscillation of a lever which carries a spring-pressed pawl. On the upward stroke the ratchet is turned by the pawl which is backed by a shoulder on the lever. On the return stroke a dog holds the ratchet-wheel from turning while the pawl snaps past.

96. Ratchet teeth are formed on a ball which rests in a socket formed at the end of a lever. A spring pawl on this lever engages the ratchet teeth at any position of the lever. This construction is useful for ratchet braces which have to be operated in inconvenient places.

97. A device for converting rotary motion into vibratory motion. A spring-pressed pin engages the teeth of a revolving crown-wheel ratchet, and is thereby caused to vibrate.

98. A device for converting reciprocating motion into intermittent rotary motion. The crown-wheel ratchet is intermittently rotated by a reciprocating lever carrying a pawl which engages the ratchet teeth.

99. Internal ratchet used on ratchet braces, etc. The drill spindle carries a number of spring-pressed pawls which bear against the internal ratchet teeth formed in the handle of the brace.

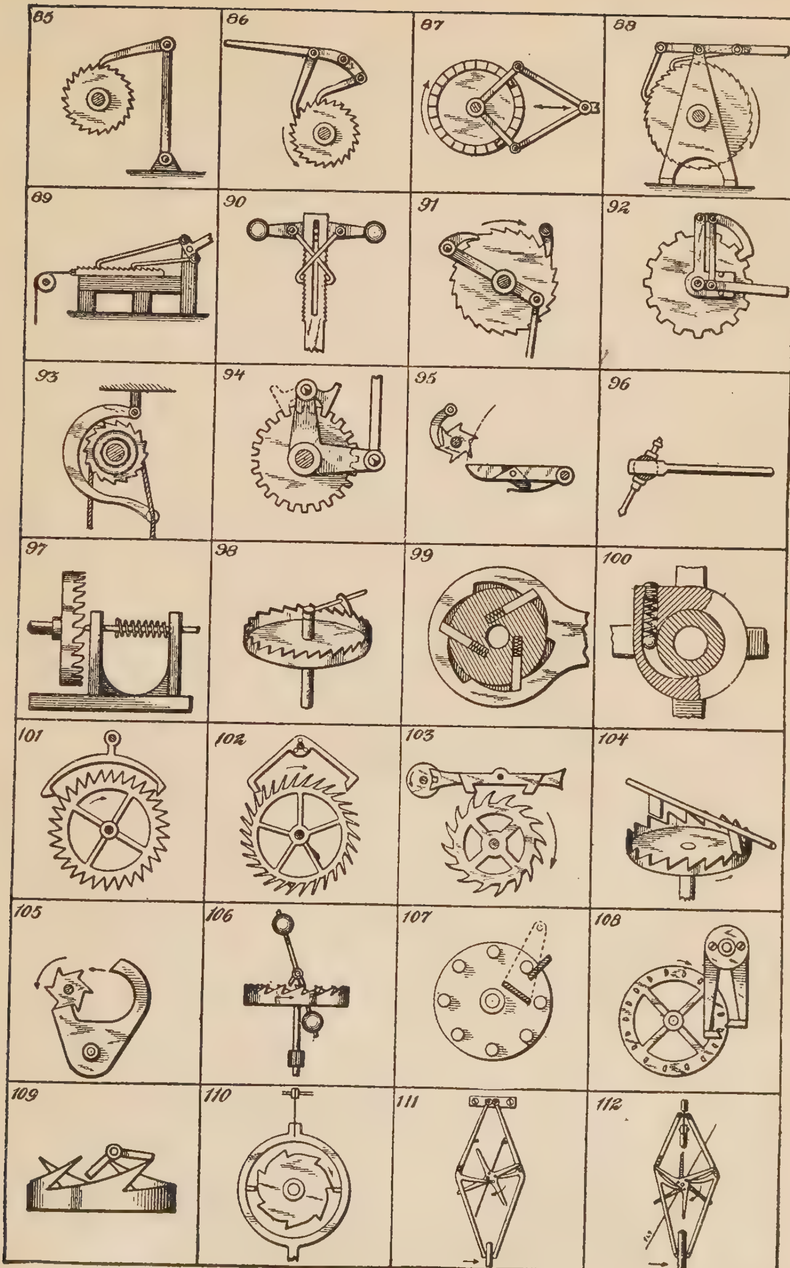
100. Ball ratchet device for lawn mowers, etc. In the hub of a wheel is a groove in which a ball is carried. A spring presses this ball down against a shaft on which the wheel turns. When the wheel rotates forward, the ball wedges in between the shaft and the groove, causing the shaft to turn with the wheel. When the direction of rotation is reversed, the ball is forced up against the spring, releasing the shaft.

ESCAPEMENTS.

101. Recoil Escapement.—This is a common form of escapement used on clocks. The pallets carried by the pendulum are so mounted that when a tooth of the escape wheel, which is driven by the clock-train, is just escaping from one of the pallets, another tooth falls on the other pallet near its point. As the pendulum swings on, however, the taper face of the pallet bearing against the tooth causes the escape wheel to turn slightly backward. As the pendulum swings back, it receives an impulse from the escape wheel which is greater by reason of this recoil. The principal value of the recoil, however, is to overcome any unevenness in the pressure exerted by the train, which might otherwise stop the clock.

102. Dead-beat Escapement.—A form of escapement used on the best clocks. The teeth of the escape wheel fall "dead" upon the pallets, that is, the pallets are so cut that as the pendulum continues to swing they slide on the teeth without turning the escape wheel backward. The ends of the pallets are formed with inclined faces, termed "impulse faces," against which the teeth of the escape wheel bear when giving impulse to the pendulum. The value of this escapement lies in the fact that it gives a very even beat of the pendulum even when there is a slight variation in the force exerted by the clock train.

103. Lever Escapement.—This is an escapement used on watches. The anchor on which the pallets are carried is secured to a lever, formed with a notch in one end. This notch is engaged by a pin on the arbor of the balance wheel. The teeth of the escape wheel alternately bear against the inclined faces of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the pallets and oscillate the lever, which turns the balance wheel alternately in opposite directions.

104. Verge Escapement.—A form of escapement used in old-fashioned watches. The escape wheel is a crown wheel, and its teeth, on opposite sides, are engaged by two pallets, carried on the shaft of the balance wheel. The escapement teeth, acting alternately on the pallets, lift and clear them, thus rocking the shaft and balance wheel, which governs the frequency of the escape.

105. Star Wheel Escapement.—The escape has but few teeth and is, therefore, called a star wheel. The pallets act on teeth that lie diametrically opposite each other. This escapement has a dead-beat action.

106. Crown Tooth Escapement.—An old form of recoil escapement, in which a crown escape wheel is used. The pallets are mounted to engage opposite sides of the wheel. This type is objectionable, owing to the fact that the pendulum must oscillate through a very wide angle in order to permit the teeth to escape from the pallets, which requires a greater pressure in the clock-train and heavier parts and produces greater friction on the pallets.

107. Lantern Wheel Escapement.—An old-fashioned type of escapement, in which the escape wheel is a lantern wheel, and the pallets are two plates set at angles on a rocking arm.

108. Pin-wheel Escapement.—A dead-beat escapement used in many of the best turret clocks. The escape wheel is formed with pins which drop on to the "dead" faces of the pallets, but give impulses to the pendulum by sliding off the inclined "impulse" faces of the pallets. It is found best in practice to cut the "dead" faces so as to give a very slight recoil.

109. Old-fashioned Crown Wheel Escapement.—This, in appearance, is quite similar to the escapement shown in Figure 106, but is different in action. The inclined faces of the teeth, which are very long, act to lift the pallets.

110. Ring Escapement.—A form of "dead-beat" escapement. The pallets are formed on the inside of the ring, within which the escape wheel turns.

111 and 112. Gravity Escapements.—A type of escapement in which the impulse from the escape wheel is not given directly to the pendulum, but through the medium of two weights, usually the arms on which the pallets are carried and which are alternately lifted by the escape wheel and dropped against the pendulum. Figure 111 shows the four-legged gravity escapement used on turret clocks. The escape wheel is formed with four legs or teeth, and carries eight pins, four on one face of the hub and four on the other. The pallet arms are pivoted as near as possible to the point from which the pendulum swings. The pallets which are formed on these arms are arranged to lie one on one side and the other on the other side of the escape wheel. The pallet arms are each provided with a stop piece against which the teeth of the escapement will alternately rest. In the illustration, a tooth of the escape wheel is resting against the stop on the right-hand arm. As the pendulum swings toward the right, the tooth will escape from the stop, permitting the wheel to rotate until it encounters the stop on the left-hand arm, at the same time a pin on the wheel engages the end of the pallet at the left, and lifts the pallet arm. In the meantime the right-hand pallet arm swings with the pendulum to the end of its stroke, but falls with it on the return stroke until stopped by a pin on the escape wheel. It will be evident that the angle through which the pallet arm falls with the pendulum is greater than that through which it is lifted by the pendulum, and it is this difference in travel which gives impulse to the pendulum. Figure 112 shows a double, three-legged escapement which is used for very large clocks. Two three-legged escape wheels are used with three lifting pins held between them like the pins of a lantern wheel. The pallets operate between the wheels. A stop piece is placed on one of the pallet arms for the forward wheel, and the other arm carries a stop for the rear wheel. The teeth of one wheel are set 60 degrees in advance of the other. The action is similar to that of the four-legged escapement. A tooth of the forward wheel is shown resting on its stop. When this is released by the swinging pendulum, the wheels rotate, lifting the left-hand pallet until a tooth of the rear wheel engages its stop. The right pallet arm, however, continues to be lifted by the pendulum, and then falls with it, giving it impulse until arrested by a lifting pin, only to be lifted again when the pendulum releases the rear wheel from its stop.

GEARING.

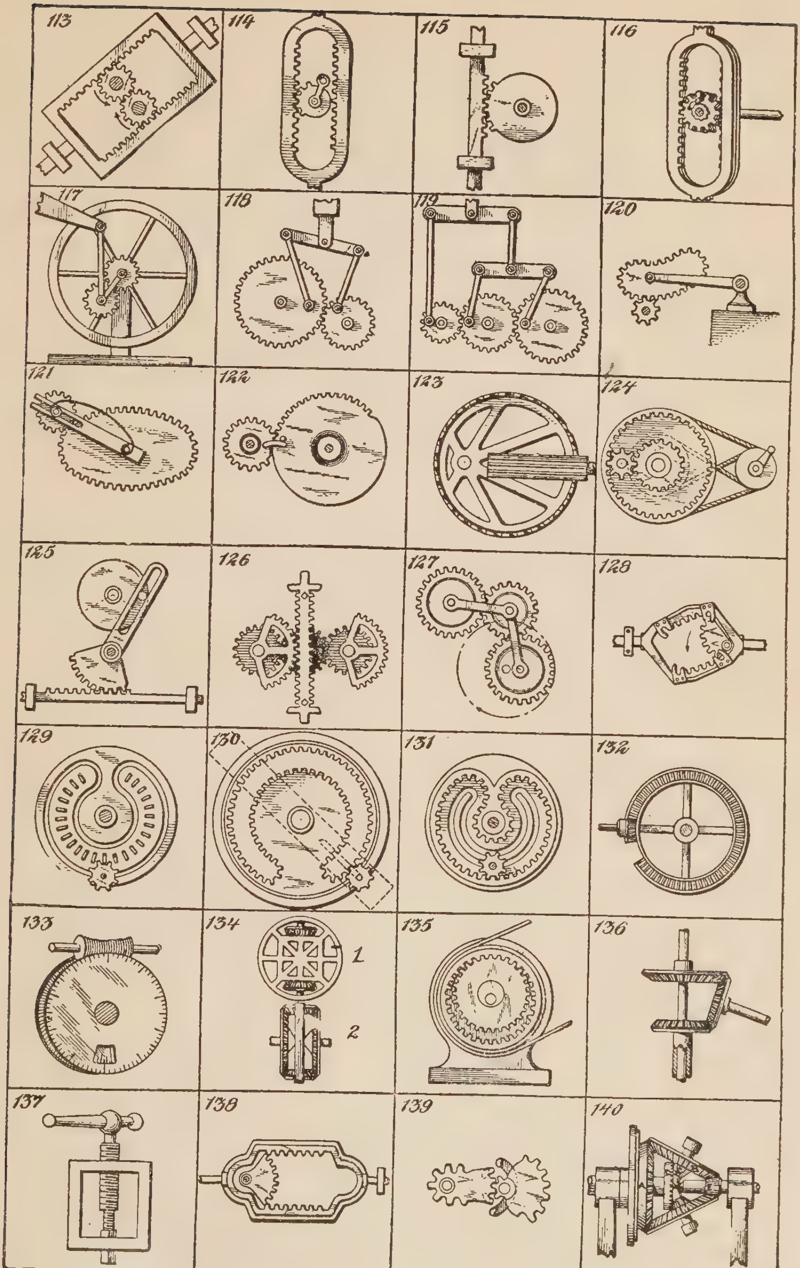
113. A means for changing rectilinear reciprocating motion to rotary reciprocating motion and vice versa. Two intermeshing pinions engage internal racks formed on opposite sides of a frame.

114. Means for changing rotary motion to rectilinear reciprocating motion. A rotating sector or pinion formed with teeth on only a portion of its periphery imparts reciprocating motion to a rack frame by first engaging the teeth at one side of the rack, and then the teeth on the other side of the rack. See Figure 115 for gravity return.

115. Another method of converting rotary motion into rectilinear reciprocating motion. A rotating sector engages the teeth of a rack during a part of its rotation and thereby lifts the rack, but as soon as the rack clears the sector teeth, it drops by gravity, ready to be lifted up when it again encounters the teeth of the sector. See Figure 114 for power return.

116 A movement designed as a substitute for a crank. The rack frame is formed with internal racks on opposite sides, but these racks lie in different planes. Two separate pinions are employed which mesh respectively with these racks. The pinions are mounted loosely on a shaft, but carry pawls which engage with ratchet wheels secured to the shaft. On the forward stroke of the rack frame the pinions will both be rotated but in opposite directions. However, due to their ratchet and pawl connection with the shaft, only one pinion turns the shaft. On the return stroke the rotation of the pinions will be reversed but the shaft will continue to rotate in the same direction driven this time by the other pinion of the pair.

117. Sun and Planet gearing. A gear wheel, called the "sun" wheel, rotating on a fixed center, is engaged by a gear wheel called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the planet wheel, which revolves about the sun wheel. This construction was used by James Watt in one of his steam engines as a substitute for a crank. The planet wheel was rigidly secured to the connecting rod and connected by an arm to the center of the sun wheel. At each complete revolution of the planet wheel about the sun wheel, the latter was caused to rotate twice.

118 and 119. Means for converting rotary motion into irregular reciprocal motion. In 118 two intermeshing spur gears are provided with crank arms connected by a working beam. If the gears are of equal size the motion transmitted to the rod secured to the working beam will be uniform. If, however, the gears are of different sizes, the motion of this rod will vary greatly. In 119 a still more complex movement is produced, since there are three intermeshing gear wheels of unequal sizes and two connected working beams.

120. Irregular oscillatory motion is given to a hinged arm by pivoting at its outer end a cam-shaped gear wheel which is rotated by a continuously driven pinion. Any desired motion of the arm may be produced by varying the shape of the cam gear.

121. Means for converting uniform rotary motion into variable rotary motion. An elliptical gear rotates at uniform speed and drives a spur pinion. The latter is secured to a shaft which slides between the arms of two forked levers. A spring keeps the pinion in mesh with the elliptical gear.

122. Means for converting constant rotary motion into intermittent rotary motion. The driving wheel is formed with teeth through a portion of its periphery equal to the toothed periphery of the pinion. The latter is cut away at one place to fit the plane portion of the driving wheel. This prevents the pinion from rotating until a pin on the wheel strikes a projecting arm on the pinion and guides the teeth of the gears into mesh with each other.

123. Means for converting uniform rotary motion into variable rotary motion. A crown wheel eccentrically mounted is driven by a pinion rotating at uniform speed. The point of engagement of the crown wheel with the pinion varies radially, causing the wheel to rotate at a variable speed.

124. The mechanism is so arranged as to impart planetary movement to a pinion. An internal gear wheel formed with a pulley groove in its periphery is mounted to rotate on a sleeve which carries a spur gear at one end and a pulley at the other. The gear wheels are belted to a driving pulley in such manner as to rotate in opposite directions. A spur pinion which fits in between the teeth of the two gears is rotated thereby on its own axis and revolves about the center of the two gears at a speed which is the differential of the speeds of the two gears.

125. The construction here shown is adapted to produce a slow forward movement of a rack with a quick return. The rack is mounted to slide longitudinally and is driven by a toothed sector. The latter is provided with a slotted arm which is engaged by a pin on a rotating disk. The forward movement will take place while the pin is passing through the larger arc subtended by the two dotted radial lines shown, and there turn while the pin is passing through the smaller arc.

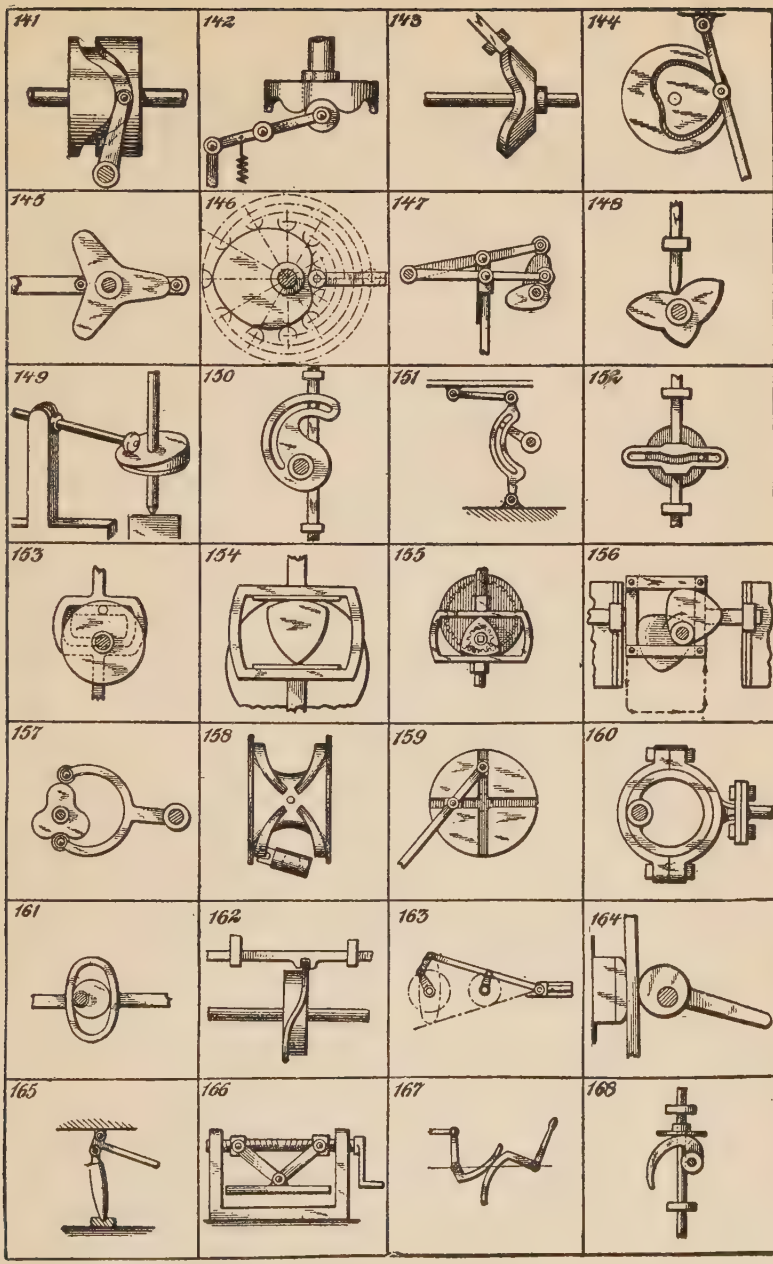
126. A means for converting reciprocating motion into continuous rotary motion. A double-faced reciprocating rack engages first one and then the other of a pair of toothed sectors. The sectors are mounted on a pair of shafts, disposed on opposite sides of the rack. The shafts carry pinions which engage opposite sides of the central gear wheel. The rotary motion alternately imparted to the sectors, is conveyed through these pinions to the gear wheel, each pinion alternately acting to drive the wheel when its respective sector is in mesh with the rack, and then to be driven by the gear wheel until its sector is brought again in mesh with the rack. Thus a continuous rotary motion is produced.

127 Mechanism for converting uniform rotary motion into irregular rotary motion. Mounted eccentrically on the driving shaft is a gear wheel which transmits motion to another gear wheel through an intermediate pinion. Pivoted to the centers of the two gear wheels are two links whose outer ends are connected by a hinge pin on which the pinion rotates. These links serve to hold the pinion constantly in mesh with the gears, no matter what the position of the eccentric is.

128. Means for converting uniform rotary motion into variable reciprocating motion. A rack frame mounted to slide longitudinally is driven by an eccentric-toothed sector. The racks are placed at an angle with the line of movement and are provided with jaws at each end adapted to mesh with pins projecting above the face of the sector. As the sector rotates it transmits a gradually accelerated longitudinal movement to the rack frame until the outer pin engages the jaw at the end of the rack. The rack frame is then driven by this pin until the opposite rack is engaged by the sector teeth.

129 to 132. Mangle Gears.—So-called because of their use on mangle machines. 129. The larger wheel is formed with a cam groove which guides the pinion. The shaft of the latter is ordinarily provided with a universal joint, which permits it to move vertically and thus keep in mesh with the crown teeth formed on the large wheel. The pinion meshes first with the outer and then with the inner ends of the teeth on the larger gear, driving the latter first in one direction and then in the other. 130 shows another form of the same movement. The pinion moves radially in the slot shown in dotted lines, and engages first the outer and then the inner line of teeth on the mangle wheel, causing the latter to rotate first in one direction and then in the other. 131. The mangle wheel is formed with an internal gear, and the pinion is guided by a cam groove. This construction and that shown in Figure 130 produce uniform motion through an almost complete rotation, and this is followed by a quick return due to the smaller radius of the inner circle of teeth. 132. In this construction, as in that of Figure 129, the same speed is maintained in both directions of rotation. The mangle wheel in Figure 132 is formed with teeth on both faces; the pinion first engages the teeth on one face of the wheel, and then passing through the opening engages the teeth on the opposite face, thus reversing the direction of rotation.

133 to 137. Differential Gear.—133. Two worm wheels, one of which has more teeth than the other, engage a single worm. Suppose that one wheel has 100 teeth and the other has 101; then at every complete rota-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tion of the latter wheel it will be one tooth behind the former wheel, and at the end of 100 rotations the former would have made a complete rotation relative to the latter. If the worm be cut with a single thread it would have to make 100 times 101, or 10,100 rotations in order to produce this result. This construction is used on certain counting devices. 134. Two bevel gears are connected by a pair of small bevel pinions mounted in a frame, as shown in the side elevation 1. If the gear wheels should be rotated at different velocities the frame would rotate at the mean velocity. 135. A rapidly rotating shaft carries a gear wheel eccentrically mounted thereon. The latter is carried along into engagement with a fixed internal gear or rack, and is thereby rotated at a slow speed. 136. Two concentrically mounted bevel gears of different diameters engage with a third bevel gear. The latter rotates at the mean of the velocities of the other two. 137. A hollow screw threaded into a frame is formed with an internal thread, of slightly different pitch, adapted to receive a smaller screw, which is so mounted in the frame that it may slide longitudinally, but cannot rotate. If the larger screw should have ten threads to the inch, and the smaller screw eleven, the latter would move outward one-eleventh part of an inch while the former was fed inward an inch.

138. Uniform rotary motion converted into reciprocating rectilinear motion. A rack frame arranged to slide longitudinally is engaged by a toothed sector which meshes with the teeth on one side of the rack to drive the frame forward, and then with the teeth on the other side to drive the frame back.

139. Variable speed gear for producing fast and slow motion. It comprises two pairs of toothed sectors so arranged as to properly mesh with each other. The driving gear shown at the right is provided with two arms which carry studs at their outer ends. These studs lie below the lower face of the gears and engage studs formed on the lower face of the driven gear, as shown in dotted lines, thus guiding the wheels after one pair of sectors have moved out of mesh and before the other pair have come into mesh with each other.

140. Mechanism for producing increased or decreased speed on the same line of shafting. A fixed bevel gear wheel, A, meshes with two bevel gear wheels, B, which in turn mesh with a pinion, E, carried on the right-hand shaft. The bevel wheels, B, are mounted in a bracket which turns freely on the shaft of pinion, E. Each wheel, B, carries a pinion, C, which meshes with a bevel gear wheel, D, carried by the left-hand shaft. The change of speed from one shaft to the other is due to the planetary movement of the wheels, B and C. When the multiple of the teeth in A and C exceeds that of B and D the shafts will rotate in opposite directions.

CAMS AND CAM MOVEMENTS.

141 and 142. Cylinder or Drum Cams.—In Figure 141 a groove is formed in the curved face of a cylinder or drum. A roller on the end of a pivoted arm fits into this groove. As the drum rotates the arm will be swung to various positions, guided by the groove in the cam. In Figure 142 the roller bears against the rim of the cylinder, which is made of such shape as to give the desired motion to the lever. In this form of cam, while the roller is positively moved down by the cam rim, it is raised up by a spring on the lever, which tends to hold it constantly against the cam. In the first type of cam the motion is positive in both directions.

143. Beveled Cam.—This form of cam is used to give motion to a lever whose axis lies at an angle with the cam-shaft. The cam is of conical form with curved edges against which the lever bears. In our illustration we have shown a sliding rod in place of a rocking lever. The conical face, it will readily be seen, must lie parallel with the plane of the rod.

144. Face Cam.—The cam groove is cut in the face of a disk, and this on being rotated guides the movement of the rocking lever which carries a roller that enters this groove.

145. Clover-leaf Cam.—This is a form of disk cam which gives a positive drive to a sliding lever. The cam acts between two rollers on the lever, and is so cut as to exactly fill the space between these rollers at all times.

146. Heart Cam.—Another form of disk cam. This is so cut as to give uniform rectilinear motion to a sliding rod which bears against its edge. To lay out this cam, divide the desired line of travel of the rod into any convenient number of equal spaces, starting from the center of the roller, and from the center of the cam describe arcs passing through the dividing points. Twice the number of radial lines should be laid off from the center of the cam, the lines being equally spaced angularly. The successive points of intersection of the radial lines and the arcs will then mark the centers for a series of arcs with radii equivalent to the radius of the roller. The curve drawn tangent to these arcs will then mark the outline of the cam.

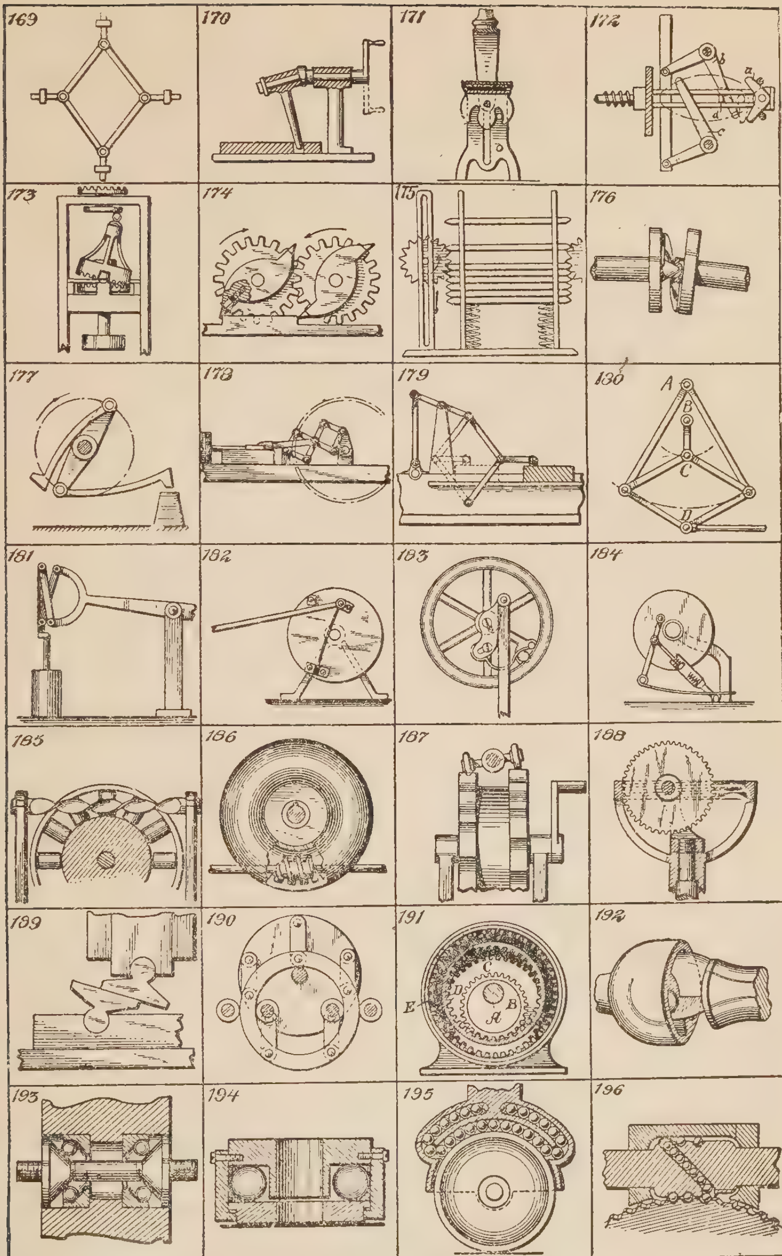
147. Means are here shown for converting rotary motion into alternating reciprocating motion of two rods. The rods are attached to pivoted levers carrying rollers which bear against the edges of two oval disk cams mounted on a rotating shaft.

148. Rotary motion is here converted into variable rectilinear motion. The end of a sliding lever rests on the irregular edge of a disk cam, and is there by caused to move up and down following the irregularities of the cam. The cam shown gives three reciprocations of the rod for each rotation of the cam shaft.

149. Means for converting rotary motion of a shaft into rocking motion of a lever. The lever is caused to rock by a cam with an oblique face on which the roller of the lever bears. This is a modification of the motion shown in Figure 142.

150. Means for converting rocking motion of a shaft into uniform rectilinear motion of a rod. The rod, which is mounted to slide in bearings, carries a pin which engages a slot in the cam on the rocking shaft. The cam slot is so cut as to give uniform motion to the rod.

151. Continuous rotary motion of a shaft is here converted into intermittent reciprocating motion of a slide. A cam lever hinged at its lower end to a fixed point is connected by a rod at its upper end, to the slide. A crank arm on the rotating shaft carries a pin which enters a curved slot in the cam lever. The crank arm causes the lever to rock, carrying the slide with it. The cam slot should form an arc with a radius equal to that of the crank arm, so that while the crank pin is passing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through this arc the slide will remain stationary. This motion is used on certain types of sewing machines and printing presses.

152. The type of cam used on the needle bars of some sewing machines. A pin on a rotating disk engages a slot in a cam yoke on the needle bar. This slot is formed with a curve at one place, which holds the bar stationary, while the pin is passing through it. This causes the needle to stop while the shuttle passes.

153. This cam motion differs from that of Figure 152, in that it causes the sliding bar to stop midway of its upward stroke and midway of its downward stroke. The cam slot comprises two parallel sections connected by two curved sections. While the pin on the rotating disk passes through the curved sections the bar is held stationary.

154. The cam here shown causes the sliding bar to stop at the end of each stroke. The cam is triangular, with curved faces, and rotates between the two parallel working faces of a cam frame on the sliding bar. While the outer face of the cam engages the frame the bar is held stationary. This is a form of cam motion used in place of an eccentric for operating the valve of a certain French engine.

155. A peculiar variable intermittent motion of the sliding rod is given by the planetary action of a cam mounted on a rotating disk. The cam shaft passes through the disk and carries a pinion which meshes with a stationary internal gear wheel.

156. A rectangular motion is imparted to the cam frame by two triangular curved cams mounted on a rotating shaft. The frame is mounted to slide laterally in bearings, which in turn are permitted to slide vertically in grooves on two stationary supports. The frame is made up of two horizontal rails on which one of the cams acts, and two vertical rails on which the other cam acts The illustration shows the frame about to be moved downward by the forward cam acting on the lower rail while the rear cam prevents any lateral movement. On the next quarter rotation of the cam shafts a lateral movement will ensue, due to the rear cam acting on the right-hand vertical rail. At the same time the forward cam will hold the frame against vertical movement. During the third quarter of the rotation the frame will be lifted, and during the last quarter it will be moved back laterally to the position illustrated. If the cams are both of the same size, the motion of the frame will trace a perfect square.

157. Means for converting rotary motion into vibrating motion. A forked lever engages opposite edges of a disk cam, and is thereby caused to vibrate. This cam, as that in Figure 145, is so cut that its opposite edges are everywhere equidistant when measured through the center. For this reason it is obvious that such a cam must always be cut with an odd number of projections.

158. A recently patented mechanism for imparting power to the dasher shaft of a churn. A rocking movement is imparted to the shaft from a rotating cam. At the upper end of the shaft is a forked piece or follower mounted to turn in a socket at right angles to the axis of the shaft. The follower engages a spline on the cam and is thereby guided first to one side, and then to the other of the cam, rocking the shaft on its axis.

159. Trammel Gear.—A reciprocating movement of the rod is produced by the rotation of a shaft, and *vice versa*. Pivoted to the rod are two blocks which slide respectively in two slots in the face of the disk which cross each other at right angles. This movement was patented seventy years ago, but is constantly being reinvented as a substitute for the crank.

160. Mechanism for converting rotary motion into reciprocating motion. This is a common form of eccentric used on steam engines, etc., for communicating a reciprocating motion to the valves from the crank shaft. The rod is provided with a circular strap which is bolted over a disk or ring eccentrically mounted on the crank shaft.

161. This form of eccentric is similar to that shown in Figure 160, but an oval cam frame or yoke is used in place of a circular strap, so as to produce a rectilinear reciprocating movement of the rod. This form of eccentric acts directly on the valve rod which travels between fixed guides.

162. Spiral Cam for converting rotary motion into reciprocating motion. The cam is formed with a flange or spline, disposed spirally on the curved face of the wheel. The spline engages a notch in a rod and gives the latter a reciprocating movement when the cam is rotated.

163. Elliptical Crank.—Two cranks are connected with a single pitman, the outer one, through a connecting link. The circular movement of the inner crank causes the outer end of the pitman to move in an elliptical orbit, thereby increasing its leverage at certain points.

164. A device for gripping a bar or cable. The bar travels between a fixed guide and the cam-shaped head of a lever. When the lever is thrown up, friction of the bar on the cam tends to rotate the latter until it becomes wedged between the cam and the fixed guide.

165. Lever Toggle-joint.—A device commonly used on letter-presses. One of the two connected arms is pivoted to the platen of the press and the other is hinged to a fixed standard. By lifting the lever on one of the toggle arms the arms will be brought into vertical alignment with each other, producing a powerful pressure on the platen.

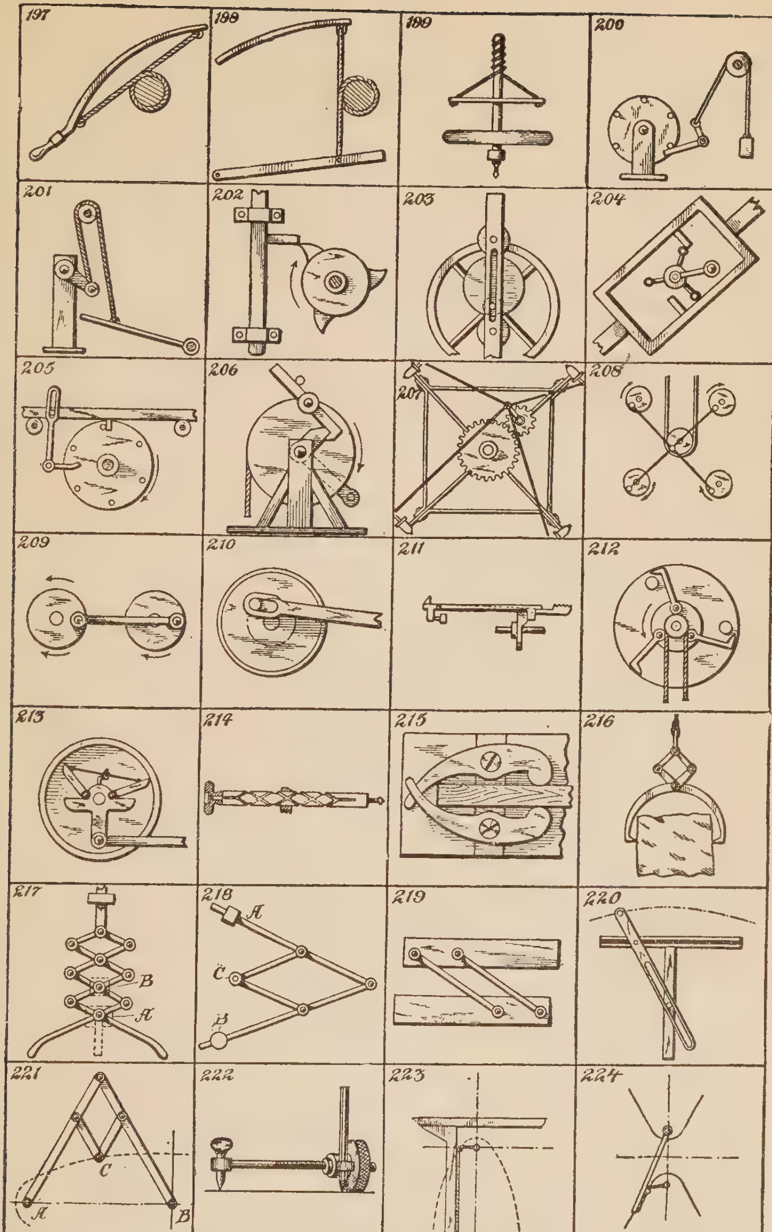
166. Screw Toggle Press.—Two toggle arms are hinged to the letter-press and at their outer ends are hinged to nuts on the feed screw. The screw is cut with right- and left-hand threads, so that when turned in operative direction it will draw the arms toward each other and press the platen downward.

167. Bell Crank Toe Levers.—Two bell crank levers are provided with projecting toes which bear against each other When one of these levers is swung on a center it causes the other to swing also, but at a variable speed, due to the varying leverage. This mechanism is used for a type of valve gear.

168. Wiper Cam.—A type of cam used on certain stamp mills to lift the hammer. The cam bears against a flanged collar on the hammer spindle, which permits the latter to rotate.

MISCELLANEOUS MOVEMENTS.

169. Device for transmitting reciprocating motion from one pair of rods to another pair lying at right angles thereto. The rods are all connected by links so that when two opposed rods are moved inward or toward each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other, the other two rods will be moved outward, and *vice versa*. Also if two adjacent rods be moved the one outward, and the other inward, the opposite rods will be moved one outward and the other inward respectively.

170. Means for converting rotary into reciprocating motion. A bent shaft carries at its outer end an arm which is loosely mounted thereon. The lower end of this arm engages a slot in a bar which is mounted to slide in suitable guides. As the bent shaft rotates, the arm which is prevented from rotating with the shaft is given a rocking movement in the direction of its axis, and thus imparts a reciprocating movement to the bar.

171. Movement used on hand stamps. The plate which carries the type normally lies face upward against an ink pad, and is formed with a flange at each end in which cam slots are cut. The type plate is pivoted in a yoke piece to which the handle is secured, the pivot pins passing through slots in the uprights of the frame. When the handle is depressed, the type plate is carried downward and at the same time rotated by engagement with two pins which operate in the cam slots so that the type will face downward when brought into contact with the paper. The parts are returned to normal position by a spring on release of the handle.

172. A peculiar device for alternately rocking a pair of levers by means of a reciprocating rod. The rod carries a bell crank lever, *A*. This lever is normally held in the position illustrated by two pins against which it is pressed by the spring-pressed rod. Two bell crank levers, *B* and *C*, connected by a bar, are hinged adjacent to the rod. With the parts in the position illustrated, when the rod is drawn forward, one arm of the bell crank, *A*, will engage a pin at the end of lever, *B*, and will be thereby turned until it engages a stop piece, *D*, on the rod, after which it will operate to swing bell crank, *B*, on its axis. Owing to the connection between the levers *B* and *C*, the latter will also be swung but in the opposite direction. On return of the rod the bell crank lever, *A*, is brought to normal position by the two position pins, and when next the rod is drawn forward, the other arm of lever *A* will engage a pin on lever *C*, returning both levers *B* and *C* to their original positions.

173. Mechanism for transmitting rotary motion at increased speed from one shaft to another in alignment therewith. The lower or driving shaft carries a crown wheel at its upper end which is engaged by a second crown wheel having universal joint connection with a stationary central post. The latter is supported from the frame by cross arms, which are adapted to engage slots cut in the second crown wheel, and thus prevent the wheel from rotating. The upwardly projecting frame of the second crown wheel is connected to a wheel on the upper shaft, but eccentric thereto, by means of a ball-and-socket joint. The driven crown wheel is thus tilted so as to engage the teeth of the driving wheel. As the latter rotates the driven wheel is given a rocking or wobbling movement, which rotates the upper shaft. A slight movement of the lower shaft thus produces a complete rotation of the upper shaft.

174. A device for converting reciprocating into rotary motion and *vice versa*. Two intermeshing gear wheels are provided with spring pawls oppositely disposed on the gears, and adapted alternately to snap into engagement with a lug on a reciprocating rod and thereby impart rotary motion to the gears.

175. A device for spacing apart a number of bars. The bars are arranged to slide with a certain amount of friction between guide pieces. Normally they are crowded together in a group by a pair of coil springs. A pair of rotating spur wheels whose teeth engage the pointed ends of the bars are mounted on either side to slide vertically in suitable guideways. The vertical movement of the gears carries the bars downward against the springs and the slow rotary movement of the gears successively releases the bars at regular intervals. The bars remain where released, being held by frictional engagement with the guide pieces.

176. An early form of flexible shaft coupling. One of the shafts is pointed and fits into a socket in the other shaft. Each shaft carries a collar and these are connected by a flat spiral spring.

177. Centrifugal hammer. Two hammers are hinged on a rapidly revolving disk. As the disk revolves, these hammers are alternately swung by the added force of gravity and of centrifugal action, on to the anvil. A very powerful stroke is thus given.

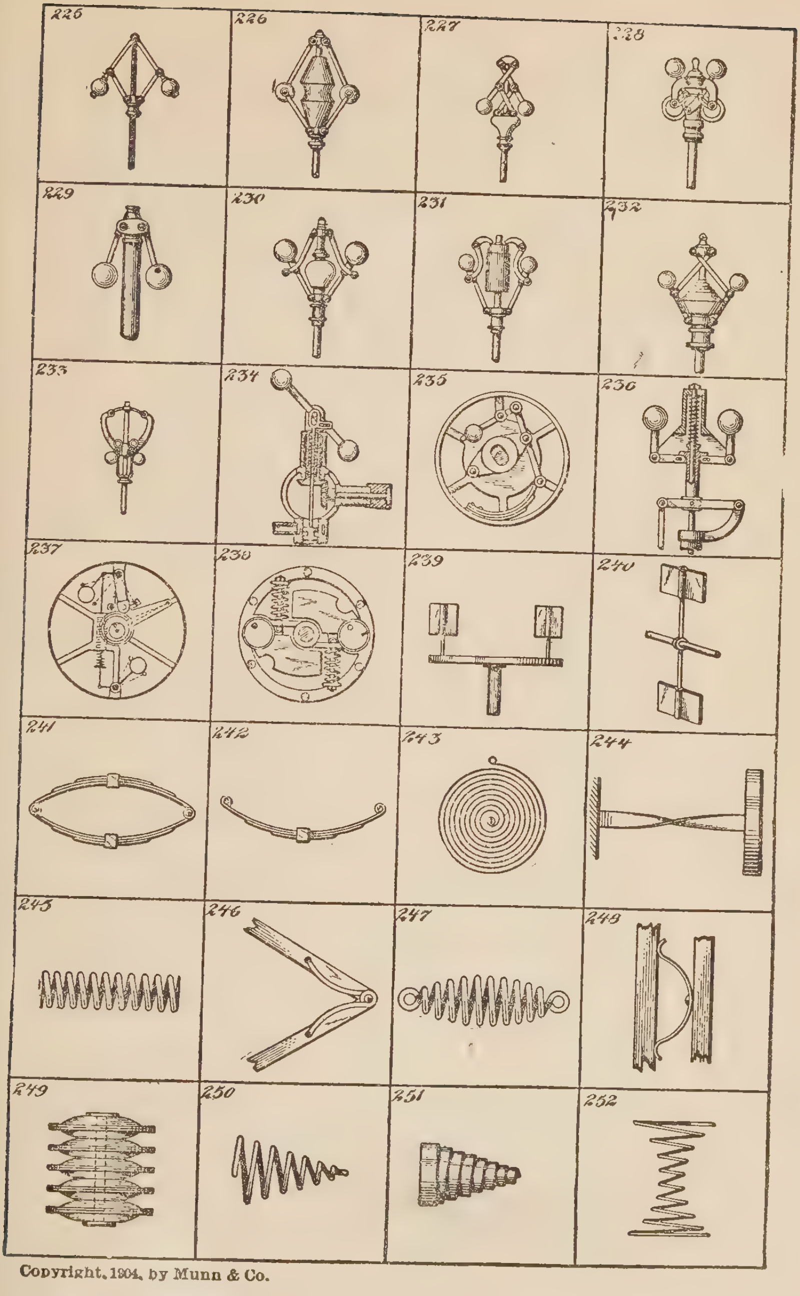
178. A device for communicating reciprocating motion of an engine to a rotating crank in such manner that the crank will have a greater throw than the stroke of the engine crosshead. The connecting rod acts on the crank shaft through a "lazy tongs" which multiplies the stroke and affords a better leverage upon the same.

179. A device for producing two rotations of the crank shaft of an engine at each complete (forward and return) stroke of the crosshead. The crosshead of the engine is connected by a rod to a pair of connected levers, one of which is pivoted on a fixed pin and the other to the working beam. Owing to the toggle action of the levers the working beam will rise and fall twice while the crosshead moves to its outer position and returns.

180. A device for converting rocking movement into rectilinear reciprocating movement, usually called "parallel" motion. Two links pivoted on the fixed pin *A* connect at their outer ends with two links pivoted on a rod at *D*. The latter links are also connected to a pair of links pivoted to a rock arm *C*. The distance between *A* and *B*, the fixed pivot of the rock arm, is equal to the distance between *B* and *C*. Owing to the fact that the double link-quadrangle swings on two pivots, it will be lengthened when swung out of the vertical position, thus giving a rectilinear motion to the rod *D*. This movement is called "Peaucellier's" parallel motion. It is used to give rectilinear movement to a pump rod or to the piston rod of an engine.

181. Another device for producing rectilinear movement of a pump rod. The rod, instead of being directly connected to the working beam of an engine, is connected thereto by cross links. This motion, however, is not a true "parallel motion," but the rod is strained by cross connection.

182 to 184. Devices for overcoming "dead" centers of cranks. In Figure 182 the pitman is connected to one end of a leaf spring, whose other end is connected to the crank disk. The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pitman is thus permitted to play between two socket lugs projecting from the face of the disk. Just before the back center is reached, the pitman slips out of engagement with the lower socket, by reason of the tensile strain on the spring, then on the return stroke, the connection of the spring being above the line of centers, the spring yields and throws the pitman back into the lower socket, and acts upon it to rotate the disk, until the forward center is reached, when the action will be the reverse of that just described. In 183 the pitman is attached to a plate secured to the flywheel at two points by screws passing through slots cut diagonally in the plate. In starting the wheel from either of its dead centers, the pitman will cause the plate to slide on its diagonal slots and the pitman will thus carry itself out of the dead center. The plate will then be returned to normal position by a spring. The device shown in 184 is specially applicable to machines operated by treadles. Attached to the pitman is a piston acting in a cylinder pivoted to the rod on which the treadle is hinged. Within the cylinder are two coil springs which alternately act on the piston to carry the crank over the two dead centers.

185. A device for transmitting motion from one shaft to another lying at right angles thereto. The driving shaft is formed with a spiral ribbon which acts between rollers radially mounted on a wheel, carried by the driven shaft. The wheel is formed with a double series of rollers, one on each side of the spiral shaft, but the forward series has been cut away in the illustration to show detail. The action is similar to that of a worm and worm wheel, but friction is reduced by the use of the rollers.

186. An internal worm gear is here shown which offers the same advantages as the internal spur gear, namely, that of greater strength due to the fact that the area of contact between the worm and the worm wheel is increased. The worm wheel is made up of two hollow sections, clamped together, but so spaced as to form a slot in the rim through which the worm shaft passes.

187. Means for converting rotary motion into rocking motion. The power shaft carries two cams formed with corrugated peripheries. On opposite sides of the rock shaft are two rollers, one for each cam. The cams are so spaced that when one roller is being lifted, the other will fall. Thus, a rocking motion is imparted to the rock shaft. The same effect may be produced by using a single broad cam for the two rollers, but spacing one roller a little in advance of the other on the rock shaft.

188. Another form of internal worm gear. A worm wheel is mounted on a stationary bracket and engages the spiral thread formed in a ring. As the ring revolves about the gear, the latter is caused to slowly rotate. As in Figure 186, a very strong construction and powerful transmission is afforded by this arrangement

189. A sliding toggle movement is here shown for producing great pressure in a direction at right angles to that of the impelling force. The toggle members are so mounted and are of such shape that they combine the action of the inclined plane with the ordinary toggle action.

190. Means for giving parallel movement to the paddles of steamboats, etc. The power shaft carries a disk which is connected by a series of hinged links with a ring held eccentrically to the shaft, between pairs of rollers. The paddles are attached to the links and are thereby kept parallel, while the disk and ring rotate. This same arrangement can be used to communicate motion to shafts lying out of alignment with each other, one of the shafts being attached to the ring.

191. Device for transmitting motion from one shaft to another at decreased velocity. The device is here shown diagrammatically. The driving shaft carries an eccentric A, upon which spur gears B and C are fitted to turn freely. The latter are permanently secured together. Wheel B meshes with internal gear D, on the driven shaft, and wheel C meshes with the stationary internal gear E. In operation the eccentric carries gear C about gear E, thereby causing it to rotate on its own center. The gear B will be revolved by the eccentric in one direction and be rotated in the opposite direction by the gear C to which it is attached, thus causing the gear D to move at a reduced speed,

192 to 196. Ball-bearing Devices.—In 192 is shown a ball-bearing knuckle joint consisting of a flanged socket member having sockets for the reception of steel friction balls, and a second member formed with flanges which bear against the friction balls. When the device is in operation, the balls will roll back and forth in their sockets at each rotation of the knuckle joint. In 193 a common form of ball-bearing is shown. The balls are held in stationary cups and bear against cones on the rotating shaft. 194 shows an end-thrust ball bearing of common form. 195 shows a ball-bearing wheel or caster. The balls are arranged to travel over an endless path, being guided from the forward end of the wheel bearing, through a passageway in the body of the caster, to the rear of the wheel bearing surface. 196 shows the same principle applied to a worm and worm wheel. The thread of the worm does not engage the teeth of the worm wheel, but communicates motion thereto through a series of balls. The latter, when they reach the end of the worm thread, are guided back through a passageway in the worm body to the beginning of the thread.

197. Means for converting reciprocating rectilinear movement into reciprocating rotary movement. A primitive form of turning lathe. The wooden shaft or other object to be turned, is mounted to rotate freely between pivot pins. A rope coiled about the shaft has its free ends secured to a spring bow. In operation, the handle of the bow is seized in one hand, and the other hand holds the tool against the work, which is rotated first in one direction, and then in the other, by moving the bow back and forth.

198. This is another form of primitive lathe which, however, is adapted to be driven by foot power. The rope, which is wound around the shaft is secured at its upper end to a spring, usually the end of a thin board and at its lower end to a pedal. When the latter is depressed, the shaft will rotate toward the cutting tool and on its release the spring will cause it to rotate back, ready for the next downward stroke of the pedal. This type of

lathe is still commonly used in some Eastern countries.

199. An ancient form of drill, but one which is still used by jewelers. Coiled about the spindle of the drill are two cords whose lower ends are secured to a cross piece mounted to slide up and down on the spindle. When the cross piece is pressed downward, it causes the cords to uncoil, rotating the spindle. When the cross piece reaches the bottom of its stroke the pressure on it is relieved, and due to the momentum of a heavy flywheel on the spindle, the latter continues to rotate, recoiling the cords and lifting up the cross piece. On the next downward stroke of the cross piece, the spindle will rotate in the opposite direction.

200. Trip hammer. A rotating disk is formed with a series of pins adapted consecutively to depress one arm of a bell crank to the opposite arm of which a hammer weight is connected by a cord. When the bell crank clears a pin on the disk, the weight drops, delivering the blow, and is then lifted again by the next pin acting on the bell crank.

201. Means for converting reciprocating motion into rotary motion. A rope attached at one end to a foot pedal passes over an intermediate pulley, and is attached at the other end to the weighted crank arm of a shaft. The arrangement is such that on the downward or power stroke of the pedal, the weighted arm will be lifted to the vertical position, when it will be assisted by gravity and its own momentum to continue its rotation and lift the pedal for the next downward stroke.

202 to 205. Means for converting rotary motion into rectilinear motion. In 202, secured to a rotating shaft is a cam formed with projecting horns, which are adapted to successively engage a lug on a sliding rod. The rod is thereby given a trip-hammer movement, dropping by gravity as the lug clears the horns. In 203, a disk mounted eccentrically on a rotating shaft is engaged on opposite sides by a pair of rollers, pivoted to a rod. As the shaft rotates, the rod will be moved up and down, following the eccentric movement of the disk. This movement is used on windmills to transmit motion from the rotating windmill shaft to the pump rod. In 204 a shaft is provided with radial arms bearing rollers at their outer ends. These are adapted to operate within a frame mounted to slide, and formed with two lugs diagonally disposed on opposite sides of the frame. When the shaft is rotated, by means of the crank arm shown, the frame will be moved first to one side by one of the rollers engaging one of the lugs, and then in the opposite direction by another of the rollers moving into engagement with the other lug. In 205, a sliding carriage is formed with a lug adapted to be engaged successively by a series of pins on a revolving disk. The carriage will be moved forward by one of the pins until the latter clears the lug, when the carriage will be moved back again by another pin engaging an arm of a bell crank whose other arm engages the carriage.

206. Automatic release for a winding drum. A winding drum is mounted to turn freely on a shaft. A hook is pivoted on the face of the drum, and when it is desired to rotate the drum the hook is brought into engagement with a tappet on the shaft. When, however, the weight has been raised to a predetermined position by the winding drum, a pin strikes the hook, releasing it from engagement with the tappet and permitting the weight to drop.

207. An amusement device called the "Flying Horse" used in parks and fairs. A frame mounted to rotate on a vertical spindle, is provided with a simple gear wheel, which meshes with a driving pinion. By alternately pulling the cords, radiating from a crank on the shaft which carries the pinion, the persons occupying the seats or horses at the corners of the frame, are enabled to keep the apparatus in motion.

208. This figure shows a single pulley driving four other pulleys by means of a cross-shaped connecting rod. This form of drive is occasionally used for rotating wheels or cylinders which lie so close to each other that no gearing or other mechanism for transmitting motion can be used.

209. This figure illustrates the rather curious fact that if two wheels are coupled together by a connecting rod, whose crank pins are respectively equally distant from the centers of the wheels, then while one wheel is constantly rotated in one direction the other may be rotated in the same direction, or in the opposite direction, as desired.

210. A stop motion used in brick machines for drawing the mold back and forth, and bringing it to rest at each stroke to permit of depositing the clay and removing the brick. A rotating wheel carries a crank pin which engages a slot in a connecting rod. At the end of its forward stroke, and at the end of its return stroke the connecting rod will remain stationary, while the crank pin moves from one end of the slot to the other.

211. A device used in sewing machines for feeding the goods under the needle. The feed bar is formed with teeth at one end and the opposite end is pivoted between the arms of a forked lever. The feed bar is lifted by a peripheral projection on a cam, and at the same time the forked lever is moved forward by a projection on the side face of the cam, which bears against a lug carried on the lever. A spring at the opposite end of the lever normally holds the lug in contact with the face of the cam.

212. Elevator safety device. Secured to the side of the elevator shaft is a plate formed with one or more studs. To the winding drum of the elevator a number of hooks are pivoted. When the drum rotates the hooks are thrown out by centrifugal action, and if dangerous speed is acquired, they swing out far enough to catch hold of one or more of the studs, bringing the drum to a stop. The shock of the sudden stoppage is usually taken up by a coil spring on the drum.

213. A device for converting oscillating motion of a lever into intermittent rotary motion. A crank arm which is provided with two pawls hinged to its upper end, is oscillated within the rim of a wheel. The pawls are connected by a cord to a small crank, which may be turned so as to bring one pawl into frictional engagement with the rim of the wheel, and thereby cause the wheel to rotate intermittently. When it is desired to reverse the direction of rotation, the crank is turned, raising the first pawl and bringing the other one into engagement with the wheel.

214. Means for converting rectilinear motion into rotary motion. This is used on certain forms of drill stocks. The drill stock is cut with two spiral grooves, one of which

is left-handed and the other right-handed. A ring on the drill stock is provided with a follower which follows one of the grooves on the forward stroke, and the other groove on the return stroke, thus causing the drill to turn always in the same direction.

215. An automatic bench clamp, used by carpenters for holding the work while planing, etc. Pivoted to the work bench are two cam levers, formed with curved ends, which are moved apart by the work as it is pressed in between them, thus causing the clamping ends of the levers to tightly grip the work.

216. Gripping tongs for lifting stones and the like. The upper arms are connected to a shackle by a pair of links so that when a pull is exerted on the shackle, the arms are drawn together, pressing the points into the stone; the heavier the stone lifted the more tightly will the arms be drawn together, thus increasing the grip on the stone.

217. A series of cross connected levers used for multiplying or reducing motion. In the illustration, the lowest pair of levers is pivoted to a fixed pin *A*, and the arrangement is such that if one pair of the crossed levers be folded together, the entire series will fold, giving the rod attached to the upper pair of levers a greatly multiplied longitudinal movement, and conversely if the rod be moved, a greatly reduced motion will be given to the lower pair of links. The extent to which the motion is multiplied or reduced is directly proportional to the number of pairs of levers in the series. This device is called a "lazy tongs." The figure also shows a means for multiplying motion imparted from one rectilinear reciprocating rod to another. If the fixed pivot of the lazy tongs be at *B*, on giving reciprocating motion to the lower rod, the reciprocating motion will be imparted to the upper rod, but the travel of the upper rod will be twice that of the lower rod.

DRAFTING DEVICES.

218. A pantograph, or an instrument for reproducing a drawing on a larger or smaller scale. It comprises two levers hinged together and connected by a pair of hinged links. One of the levers carries a slide, *A*, in which a pencil is secured. The other lever carries a pivot pin, and the tracing point is located at *C*. In use the device is made to turn on the fixed point at *B*, then on moving the tracing point *C* over a drawing, the same will be reproduced by the pencil at *A*. By varying the positions of the pencil and the pivot pin on their respective levers, the reproduction may be made larger or smaller than the original as desired.

219. This figure shows the "parallel ruler," a device used for drawing parallel lines. Two parallel rulers are connected by a pair of parallel links of equal length. The rulers will then always lie parallel to each other, whether swung apart or moved together.

220. A device for drawing a conchoid curve. A conchoid curve may be described as a curve of such form that when measured along lines drawn from a fixed point called the pole, it will, at all points, be equidistant from a straight line, called the asymptote. The device shown comprises a T-square with grooved head-piece adapted to receive a slide pivoted to a bar. A slot in the lower end of this bar engages a pin on the blade of the T-square and the opposite end of the bar carries the scribing pencil. The pin represents the pole and the grooved head of the T-square represents the asymptote. The curve traced by the pencil when measured along the bar lies everywhere equidistant from the asymptote.

221. An ellipsograph or a device for drawing ellipses. This is similar to the pantograph shown in Figure 218. The fixed pivot, however, is at *B*, the tracing point at *A*, and the pencil at *C*. When *A* is moved in a straight line toward or away from *B*, the pencil *C* will trace an elliptical curve.

222. A device for drawing a helical curve. A rod provided with a pivot point is threaded to receive a nut with a milled flange. As the rod is moved about its center, the nut is rotated by a frictional contact of the flange with the drawing paper, and is thus slowly fed toward or away from the center. A pencil carried by a sleeve on this nut will then trace a helical curve.

223. A device for describing parabolas. A pin is placed at the focus of the desired parabola and a straight-edge is placed on the line of the directrix. A slack cord is secured at one end to the pin, and at the other to the blade of a square whose stock bears against the straight edge. The slack of the cord is taken up by the pencil, which bears against the blade of the square. Sufficient slack is provided to make the distance of the pencil from the focus equal to its distance from the straight-edge or directrix. The curve then described by the pencil while keeping the cord taut against the square, as the square is moved along the straight-edge, will be a parabola.

224. A device for describing hyperbolas. The two pins shown represent the foci of two opposite hyperbolas. A ruler turns on one of these pins as a center, and its opposite end is connected with the other pin by a slack cord. The slack of the cord is taken up by the pencil which bears against the ruler. The curve described will then fulfil the conditions of a hyperbolic curve, which requires that the distance from any point in the curve to its focus, minus the distance from that point to any other fixed point or focus, should always be a constant quantity.

GOVERNORS.

A governor of a steam engine is a device for automatically operating the throttle, or for shortening the stroke of the slide valve when the engine attains a dangerous speed.

225. Watt's Governor.—When a dangerous speed is acquired, the centrifugal force acting upon a pair of balls tends to lift a sleeve which, through a bell crank, operates the throttle.

226. Porter's Governor.—The operation is very similar to that of Watt, but the balls are required to lift a weight which may be adjusted as desired.

227. Kley's Cross Arm Governor.—The degree of sensitiveness is governed by the length of the cross arms, and also by an adjustable weight, which is lifted by the balls.

228. Buss' Governor.—Two pairs of balls are used, one pair acting to counterbalance the other.

229. Tangye's Governor.—The balls when thrown out by centrifugal action depress a rod in the hollow central shaft and this rod acts directly on the block in the link thus shortening the stroke of the slide valve.

230 and 231. Proell's Governor.—In 230 the balls, aside from lifting a weight, act to compress a spiral spring. In 231 the outward movement of the balls is controlled by an air dashpot.

232. Cosine Governor.—A cross arm governor which acts to raise a weight.

233. Parabolic Governor.—The balls move on parabolic guide arms, which modify the effect of the centrifugal force, and produce equal valve movement, which is exactly proportional to the speed of the engine.

234. Oscillating Lever Governor.—The balls are secured to the ends of a lever, which assumes a more horizontal position as the speed of the engine increases. A spring normally holds the arm in the tilted position illustrated.

235. Sweet's Flywheel Governor.—The centrifugal action of the ball moves the eccentric toward the center, thus reducing the stroke of the slide valve. A leaf spring resists the centrifugal action of the ball.

236. Hartnell's Expansion Governor.—The balls are thrown out by centrifugal force against the action of a spring raising the block in the link and thus varying the stroke of the valve.

237. Hartnell's Crank Shaft Governor.—The weights operate against the spring to move a toothed sector, which moves the eccentric toward the center of the crank shaft, thus varying the stroke of the slide valve.

238. Turner's Crank Shaft Governor.—The weights have bearings in the side plates of the governor. They also carry pins by which they are connected to the eccentric. When the weights are thrown out by centrifugal action, they move the eccentric toward the center of the crank shaft.

239 and 240. Vane Governors.—The shaft is prevented from rotating too rapidly by the atmospheric resistance acting on a pair of vanes. This resistance may be varied by adjusting the vanes to different angles. In some types of vane governors the inclined vanes serve to lift a sleeve, cutting off the supply of power.

SPRINGS.

241 and 242. Laminated or Carriage Springs, used on carriages tó take up the jolts of the wheels in passing over uneven roads. 241 shows the elliptical form, and 242 the semi-elliptical form. They are built up of flat spring metal strips.

243. Watch or Clock Spring, used to drive a watch or clock train. The spring is formed of a flat spring metal strip, wound into a flat coil.

244. Ribbon Spring.—A strip of flat spring metal mounted to exert a torsional pressure.

245. Spiral Spring.—A length of round spring wire wound into spiral form. This spring could be used either as a tension or as a compression spring, though usually it has the form shown in Figure 247 when used as a tension spring. A spiral spring should never be extended or compressed more than one-third of its length.

246. Sear Spring.—This spring gets its name from its use in gun locks for causing the sear to catch in the notch of the tumbler. However, the spring is here shown as holding apart the arms of a compass.

247. Tension Spiral Spring.—A spiral spring which tapers toward the ends so that the pull will come centrally on the spring, thus giving an even tension and avoiding side strains.

248. Flat or Leaf Spring.—A strip of flat spring metal used chiefly as a compression spring. A spring of this type is apt to lose its resiliency after continued use.

249. Disk Spring.—A compression spring made up of a series of dished disks or plates.

250. Helical Spring.—This spring differs from the spiral spring, Figure 245, in that it is formed by being wrapped around a cone, whereas a spiral spring is formed by being wrapped around a cylinder. The helical spring may safely be compressed until it lies flat like a clock spring.

251. Volute Spring.—A compression spring formed by coiling a flat spring ribbon into a helix.

252. Furniture Spring.—A compression spring comprising a double helical spring used in furniture to support the cushioned backs or seats of chairs. This spring is also used in bed springs.

TRANSMISSION OF POWER BY BELTING.

The Tenacity of Good New Belt Leather varies from 3,000 lb. to 5,000 lb. per square inch of sectional area.

The Coefficient of Friction between ordinary belting and cast-iron pulleys is about .423.

The Thickness of Belts varies from three-sixteenths to five-sixteenths of an inch, or an average of one-fourth of an inch.

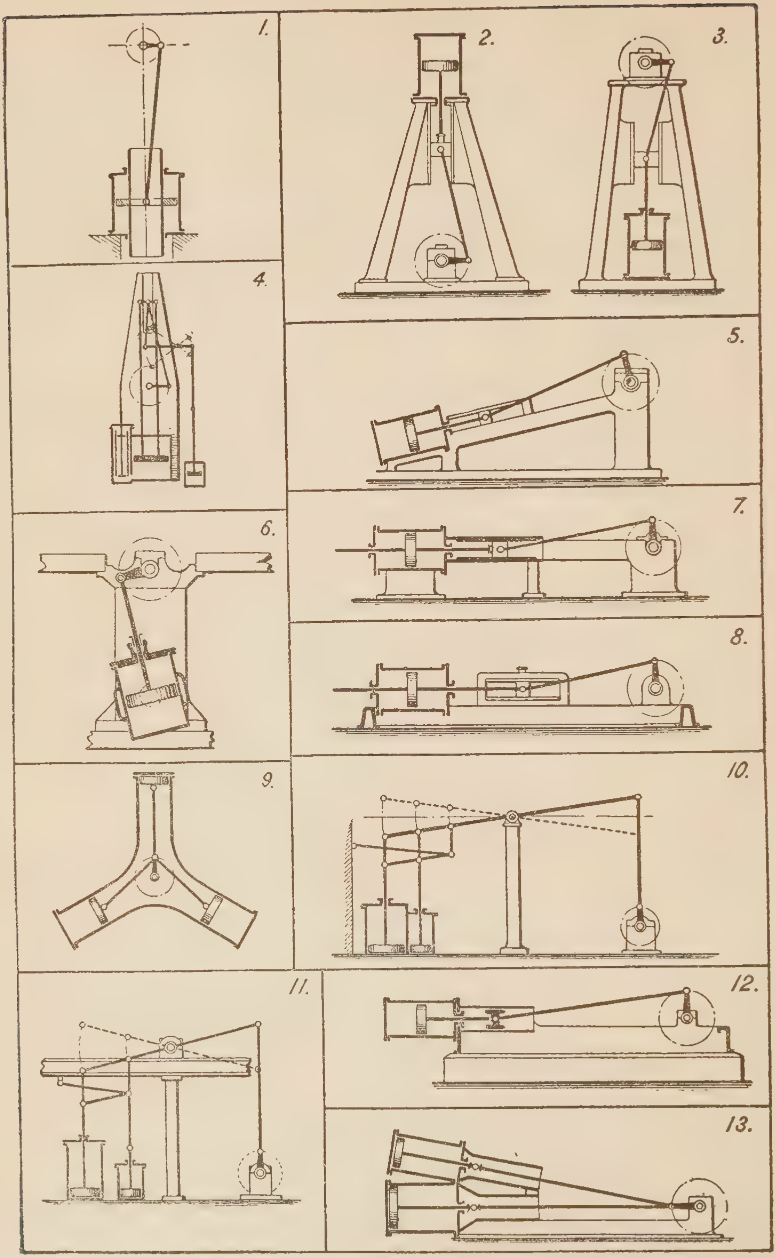
Tenacity of Riveting and Lacing.—The ultimate tenacity of good single leather belting may be taken at about 1,000 lb. per inch in width; the corresponding strength of a riveted joint being about 400 lb., a butt laced joint about 250 lb., and an ordinary overlap laced joint 470 lb. It is not customary, however, to allow an effective strain of more than one-fourth these amounts.

Working Stress of Belts.—The following are the effective working stresses allowed for the different kinds and thicknesses of belts referred to in the table of powers.

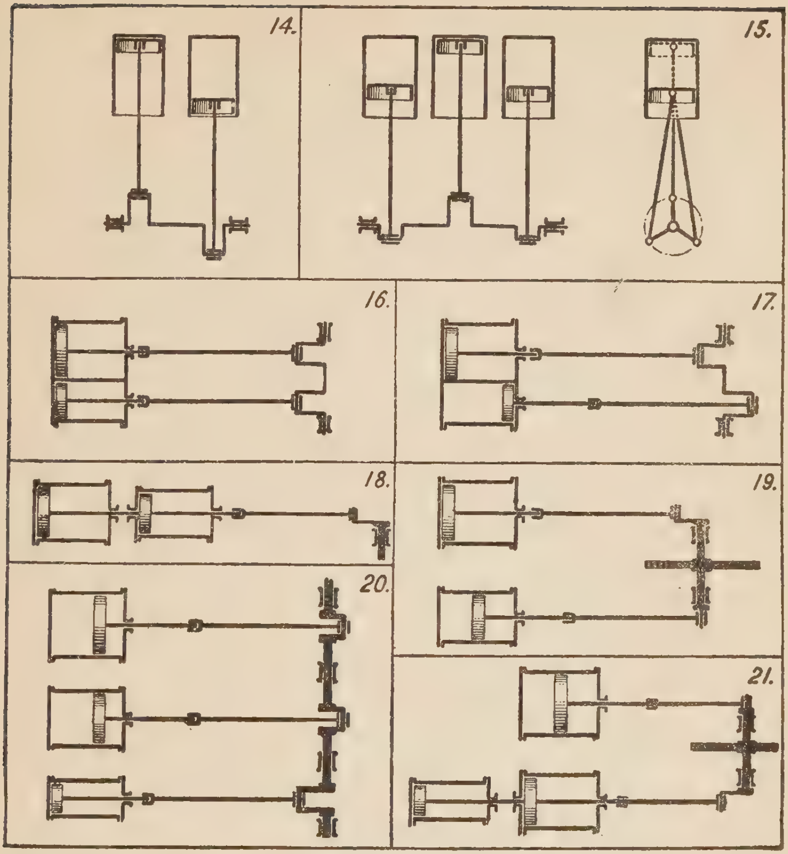
Ordinary single belts,			50 lb.
Light double belts,			70 lb.
Heavy double belts,			90 lb.
Link belts,	$\frac{3}{8}$ in.	thick,	42 lb.
" "	$\frac{1}{2}$ in.	"	48 lb.
" "	$\frac{5}{8}$ in.	"	57 lb.
" "	$\frac{3}{4}$ in.	"	66 lb.
" "	$\frac{7}{8}$ in.	"	78 lb.
" "	1 in.	"	90 lb.

Speed of Belting.—On ordinary shop line shafts the velocity of the belts varies from 1,000 ft. to 1,500 ft. per minute. Lathe belts vary from 1,500 ft. to 3,000 ft. per minute.

Stress on Shafting.—The cross stress on shafting arising from the sum of the tension on the two sides of the belt may be taken at 90 lb. per inch in width.—Practical Electrical Engineers' Pocket Book and Diary.



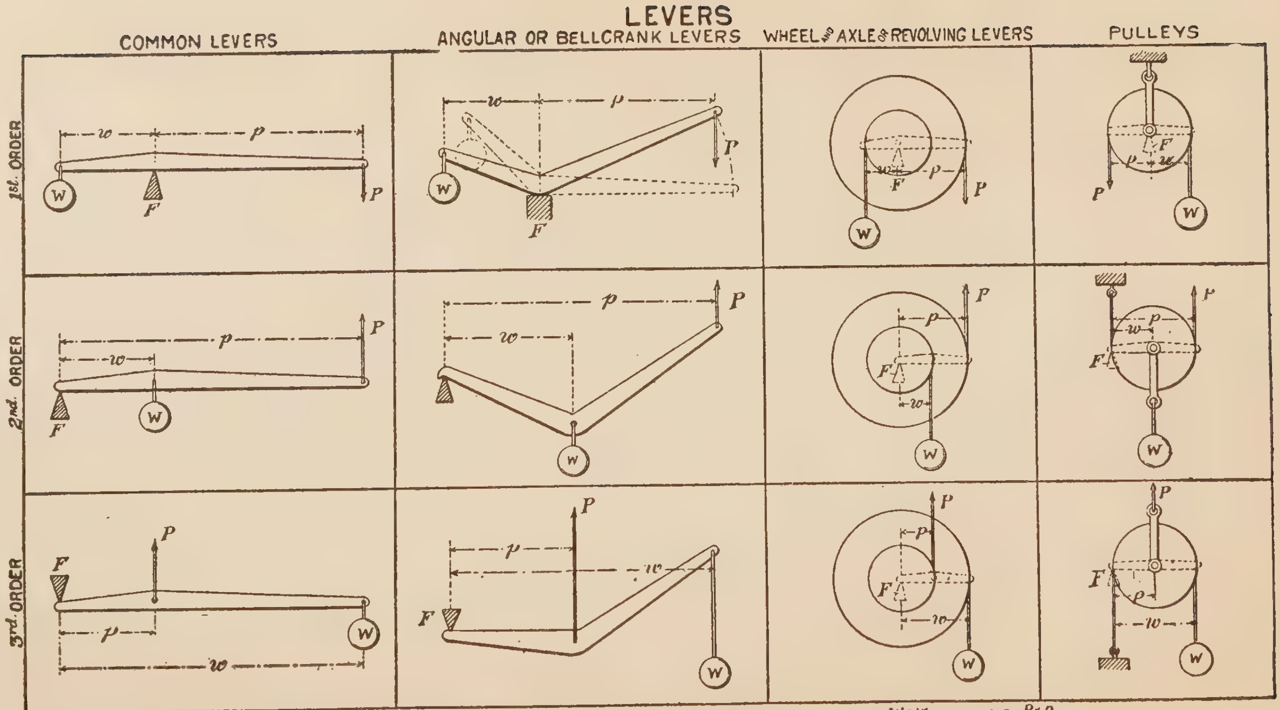
—From Haeder & Powles' Handbook on the Steam Engine.



—From Haeder & Powles' Handbook on the Steam Engine.

TYPES OF ENGINES.

1. Trunk Engine.
2 and 3. Vertical Engines.
4. Steeple Engine.
5. Inclined Frame Engine.
6. Oscillating Engines.
7. Corliss Frame or Girder Engine.
8. Horizontal Engine.
9. Radial Engine.
10. Beam Engine.
11. Beam Engine
12. Self Contained Horizontal Engine.
13. Inclined Cylinder Engine.
14 Double Cylinder with Cranks opposite or at 180°.
15. Three Cylinder Engine with Cranks at 120°.
16. Compound Woolf Engine with Cranks together.
17. Compound Woolf Engine with Cranks opposite or at 180°.
18. Compound Tandem Engine with Receiver.
19. Compound Engine with Cylinders side by side and Cranks at 90°.
20. Triple Expansion Engine, Cylinders side by side and Cranks at 120°.
21. Triple Expansion Engine, semi-tandem: Two Cranks at 90°.



P=POWER W=WEIGHT F=FULCRUM p=POWER ARM AND w=WEIGHT ARM $P=\frac{W \times w}{p}$ AND $W=\frac{P \times p}{w}$

MACHINE ELEMENTS I.

CHAPTER II.

MACHINE ELEMENTS

The Machine Elements or Powers are the Lever and the Inclined Plane. Every machine when analyzed is found to be made up of these elements, either singly or in combination; for example, pulleys, gear wheels, etc., are forms of levers, while screws, cams, etc., are forms of inclined planes.

There are four distinct types of levers, as shown in our illustration.

1st. The Common Lever, consisting of a straight inflexible bar movable on a fulcrum. The section of the bar extending from the fulcrum to the point where the power is applied is called the Power Arm, and the section extending from the fulcrum to the point where the weight is applied is called the Weight Arm.

2d. The Angular or Bell Crank Lever. This is distinguished from the Common Lever in having its power arms disposed at an angle to the weight arms.

3d. The Wheel and Axle, or Revolving Lever. A wheel and axle or two concentric wheels take the place of the power and weight arms. The weight is attached to a rope coiled on one of the wheels, and the power is attached to a rope coiled on the other wheel. The relation of this lever to the common lever is indicated by the dotted lines, and it will be evident that this relation remains constant even when the wheels are revolving.

4th. The Pulley. Another type of revolving lever, but differing from the wheel and axle type in that a single wheel is used and the fulcrum is not necessarily always at the center of the wheel.

Each of these types of the simple lever is capable of three different arrangements usually termed "Orders." In the First Order the fulcrum lies between the weight and the power. In the Second Order the weight lies between the fulcrum and the power. In the Third Order the power lies between the fulcrum and the weight. The second order gives the longest power arm relative to the weight arm, and consequently is the most powerful lever of the three. The formulæ for determining the amount of power required to balance a given weight, are given at the bottom of the illustration. In measuring the arms of the angular levers the measurements should not be taken along the length of the arms, but in the horizontal plane as shown, because this measurement represents the true theoretical length of the lever arm. As the lever is moved about the fulcrum, the ratio of the power arm to the weight arm changes as indicated by dotted lines in the first order of angular levers, because the arm that is approaching the horizontal plane is increasing in length, while the other which is moving toward the vertical plane is decreasing in length. The same is true in a modified form of the second and third orders of angular levers.

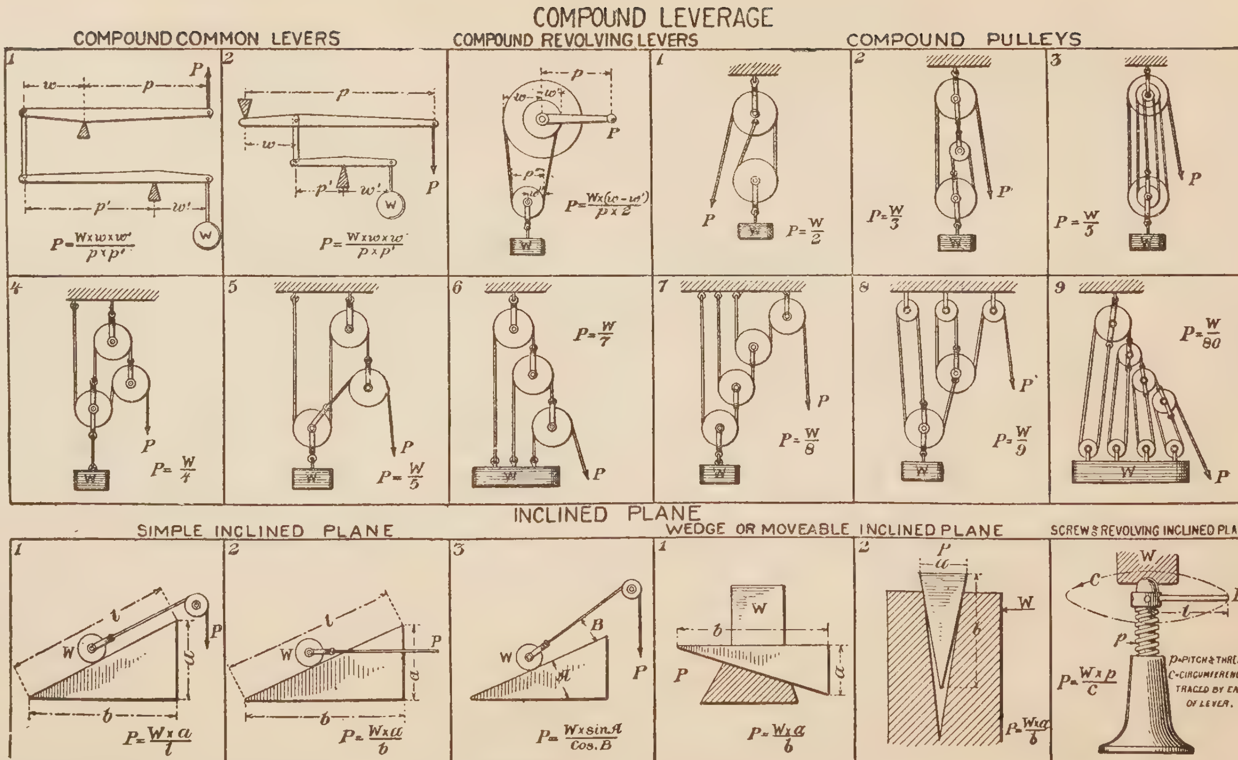
In the case of the pulleys the power and weight arms bear a definite relation to each other. No matter what their size may be, the power arm will always be of the same length as the weight arm in pulleys of the first order, consequently the power must be equal to the weight in order to keep the lever in equilibrium. In pulleys of the second order the power arm will be twice the length of the weight arm, consequently the power must be equal to half of the weight in order to keep the lever in equilibrium; and in pulleys of the third order the power arm will be half the length of the weight arm, consequently the power must equal twice the weight in order to maintain the equilibrium of the lever.

The compound levers consist of two or more simple levers of the same or different orders coupled together, either for the purposes of convenience or to increase the power.

Of the two compound common levers illustrated, Figure 1 shows two common levers of the first order coupled together, and Figure 2 represents a common lever of the first order coupled to a common lever of the second order.

The compound revolving lever illustrated is a combination of a wheel and axle of the second order, operating a pulley of the second order. This compound lever is also called a "Chinese windlass," owing to its early use by the Chinese for lifting heavy weights, such as draw-bridges, etc.

The compound pulleys or tackle shown are various combinations of pulleys of the same or different orders. As in the case of the simple pulleys, the weight and power arms bear a constant relation to each other, and it is therefore possible to give the numerical value of the power in terms of the weight, or *vice versa*, afforded by the different types of tackle, regardless of the size of the individual pulleys they comprise. The following simple formula is applicable to all tackle in which a continuous length of rope is used, as in Figures 1, 2, and 3: *Power equals weight divided by the number of rope parts supporting the weight.* In Figure 3, for instance, there are five such parts, not counting of course the part on which the power is applied. Figures 4 to 9 are all rather complex, owing to the fact that the power is transmitted to the weight through one or more movable pulley blocks connected by separate ropes. Figures 4 and 5 show tackle arrangements called Spanish burtons. A general formula, applicable to any number of pulleys arranged as in Fig. 6, is $P=\frac{W}{2^n-1}$,



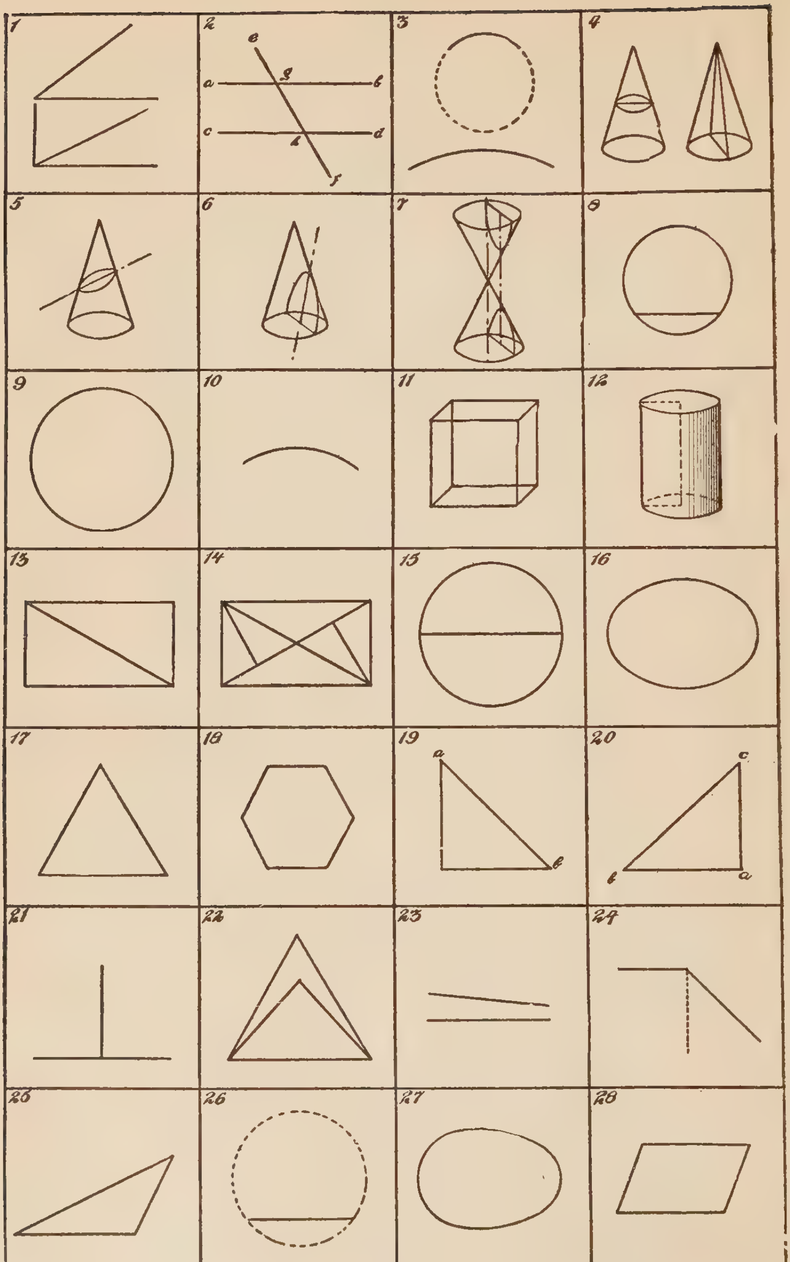
MACHINE ELEMENTS II.

in which P represents the power, W the weight, and n the number of ropes used. The general formula for the arrangement shown in Figure 7 is $P=\frac{W}{2^n}$. The general formula for the arrangement shown in Figure 8 is $P=\frac{W}{3^n}$. The general formula for the arrangement shown in Figure 9 is $P=\frac{W}{3^n-1}$.

There are three general classes of inclined planes, the simple inclined plane, the wedge or movable inclined plane, and the screw or revolving inclined plane. There are three general types of simple inclined planes, as illustrated. 1st. That in which the power acts in a direction parallel with the inclined face of the inclined plane. 2d. That in which the power acts parallel with the base of the inclined plane. 3d. That in which the power acts at an angle both to the face and to the base of the inclined plane. The formulæ for determining the mechanical advantage secured by the different forms of inclined planes are given in the illustration. In the third type of inclined plane the relation of power to weight changes as the weight is drawn up the plane, owing to the fact that the angle B becomes gradually larger.

There are two types of wedges, the single wedge and the double wedge. The latter is the more common type.

Under revolving inclined planes we have the screw together with the cam (not illustrated here), which are more commonly used in machinery than any other type of inclined plane.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CHAPTER III.

GEOMETRICAL CONSTRUCTIONS

GEOMETRICAL FIGURES

1. Acute Angle.—An acute angle is less than a right angle, or less than 90 degrees.

2. Alternate Angles.—The internal angles made by two lines with a third, on opposite sides of it. If the two lines are parallel, the alternate angles are equal. If the parallels AB, CD, be cut by the line EF, the angles AGH, GHD, as also the angles BGH and GHC, are called alternate angles.

3. Arc.—Any part of the circumference of a circle or other curve; a segment of a circle.

4, 5, 6, and 7. Conic Sections.—Formed by the intersections of cones and planes. The conic sections are the ellipse, parabola, and hyperbola. If the section be taken parallel to the base of the cone its outline will form a perfect circle. If the section be taken parallel to one side of the cone it will in outline have the form of a parabola (6). If the section be taken parallel to the axis of the cone its outline will have the form of a hyperbola (7). Any other section through the cone will in outline have the form of an ellipse (5).

8. Chord.—A right line marking the extremities of the arc of a circle.

9. Circle.—1. In geometry, a plane figure, comprehended by a single curve line, called its circumference, every part of which is equally distant from a point called the center. Of course all lines drawn from the center to the circumference, or periphery, are equal to each other. 2. In popular use, the line that comprehends the figure, the plane or surface comprehended, and the whole body or solid matter of a round substance, are denominated a circle; a ring; an orb; the earth.

10. Curve.—A curve line is one which may be cut by a right line in more points than one. A curve line is that which is neither a straight line nor composed of straight lines.

11. Cube.—A regular, solid body with six equal square sides.

12. Cylinder.—A solid body supposed to be generated by the rotation of a parallelogram round one of its sides; or a long, circular body, of uniform diameter, and its extremities forming equal parallel circles.

13. Diagonal.—The line extending from one angle to another of a quadrilateral or multilateral figure, and dividing it into two parts.

14. Diagram.—A figure, draught, or scheme delineated for the purpose of demonstrating the properties of any figure, as a square, triangle, circle, etc.

15. Diameter.—A right line passing through the center of a circle, or other curvilinear figure, terminated by the curve, and dividing the figure symmetrically into two equal parts.

16. Ellipse.—In conic sections, a figure formed by the intersection of a plane and cone when the plane passes obliquely through the opposite sides of the cone.

17. Equilateral Triangle.—A triangle having all three sides equal.

18. Hexagon.—A plane figure of six sides and six angles. If the sides and angles are equal, it is a regular hexagon. The cells of honey-comb are hexagons, and it is remarkable that bees instinctively form their cells of this figure, which fills any given space without any interstice or loss of room.

19. Hypothenuse.—The subtense or longest side of a right-angled triangle, or the line that subtends the right angle.

20. Rectangular Triangle.—If one of the angles of a triangle is a right angle, the triangle is rectangular.

21. Right Angle.—A right angle is one formed by a right line falling on another perpendicularly, or an angle of 90 degrees, making the quarter of a circle.

22. Isosceles Triangle.—If two of the sides only are equal in a triangle it is an isosceles or equicrural triangle.

23. Oblique Line.—An oblique line is one that, falling on another, makes oblique angles with it.

24. Obtuse Angle.—An angle greater than a right angle, or containing more than 90 degrees.

25. Scalene Triangle.—One in which all the three sides are unequal.

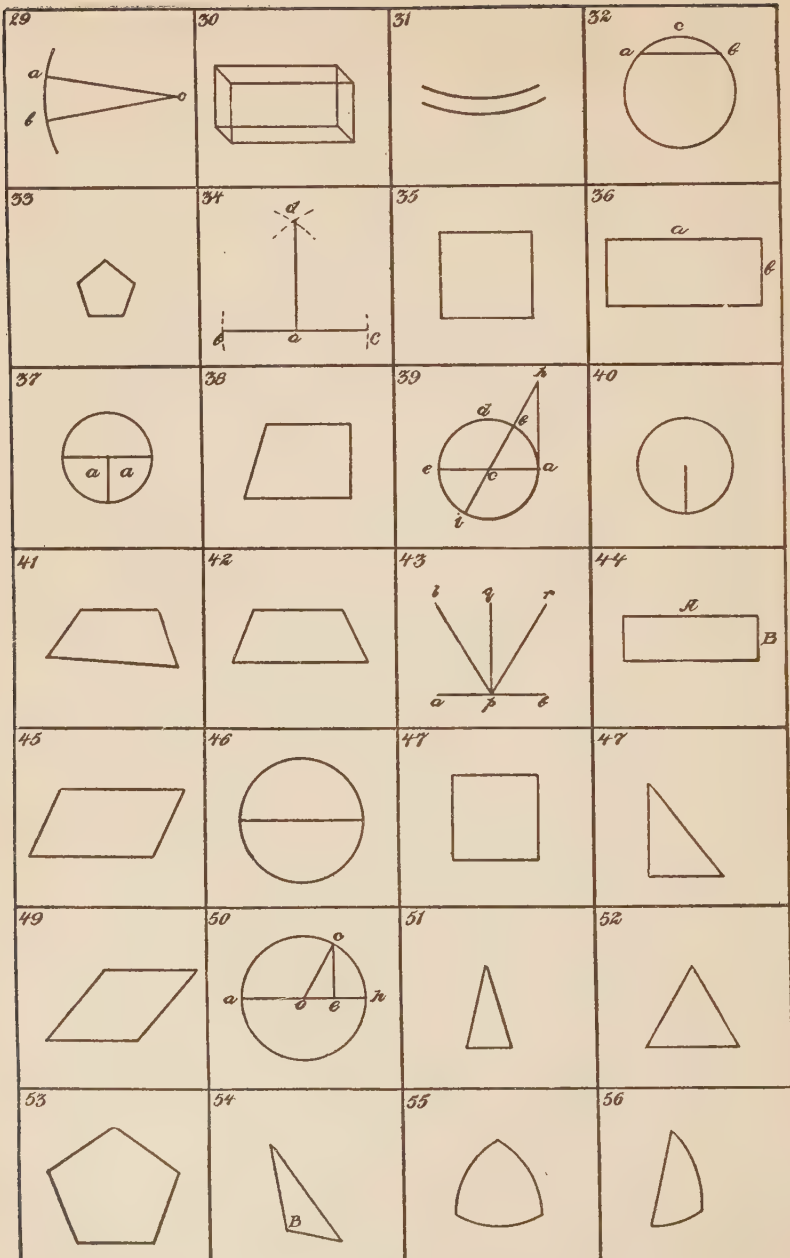
26. Secant.—The secant of a circle is a line drawn from the circumference on one side to a point without the circumference on the other.

27. Oval.—A body or figure in the shape of an egg, or of an ellipse.

28. Parallelogram.—1. In geometry, a right-lined quadrilateral figure, whose opposite sides are parallel, and consequently equal. 2. In common use, this word is applied to quadrilateral figures of more length than breadth.

29. Sector.—A part of a circle comprehended between two radii and the included arc; or a mixed triangle, formed by two radii and the arc of a circle.

30. Parallelopiped.—A regular solid comprehended under six parallelograms, the opposite ones of which are similar, parallel, and equal to each other; or it is a prism whose base is a parallelogram. It is always triple to a pyramid of the same base and height. Or a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parallelopiped is a solid figure bounded by six faces, parallel to each other, two and two.

31. Parallel Lines.—One line is parallel to another, when the lines are at an equal distance apart throughout the whole length.

32. Segment of a Circle.—That part of the circle contained between a chord and an arc of that circle, or so much of the circle as is cut off by the chord. The segment of a sphere is a part cut off by a plane.

33. Pentagon.—A plane figure having five angles, and consequently five sides.

34. Perpendicular.—In geometry, a line falling at right angles on another line, or making equal angles with it on each side. Thus if the straight line AD, falling on the straight line BC, make the angles BAD, DAC equal to one another, AD is called a perpendicular to BC.

35. Quadrangle.—A plane figure having four angles, and consequently four sides.

36. Rectangle.—A four-sided figure having only right angles. A right-angled parallelogram.

37. Quadrant.—The quarter of a circle or of the circumference of a circle.

38. Quadrilateral.—Having four sides, and consequently four angles.

39. Tangent.—In the figure, let AH be a straight line drawn touching the circle ADE at A, one extremity of the arc AB, and meeting the diameter IB produced, which passes through the other extremity B to the point H; then AH is the tangent of the arc AB, or of the angle ACB, of which AB is the measure.

40. Radius.—A right line drawn or extending from the center of a circle to the periphery; the semidiameter of the circle. In trigonometry, the radius is equal to the sine of 90 degrees.

41. Trapezium.—A plane figure contained under four right lines, of which no two are parallel.

42. Trapezoid.—A plane, four-sided figure, having two of the opposite sides parallel to each other.

43. Reflection.—In the figure, let AB represent a smooth polished surface, or mirror, and suppose a ray of light proceeding in the direction LP to impinge on the surface at P, and to be reflected from it in the direction PR. From P draw PQ perpendicular to AB, then the angle LPQ is called the angle of incidence, and QPR the angle of reflection.

44. Superficies. A superficies consists of length and breadth; as, the superficies of a plate or of a sphere. Superficies is rectilinear, curvilinear, plane, convex, or concave.

45. Rhomboid.—A figure having some resemblance to a rhomb; or a quadrilateral figure whose opposite sides and angles are equal, but which is neither equilateral nor equiangular.

46. Semicircle.—The half of a circle, the part of a circle comprehended between its diameter and half of its circumference.

47. Square.—A rectilinear figure having four equal sides and four right angles.

48. Rectilinear Triangle.—One in which the three lines or sides are all right lines, as distinguished from curvilinear triangle.

49. Rhomb, Rhombus.—An oblique-angled, equilateral parallelogram, or a quadrilateral figure whose sides are equal and the opposite sides parallel, but the angles unequal, two of the angles being obtuse and two acute.

50. Sine.—In the circle ACH, let AOH be a diameter, and let CE be perpendicular thereto; then shall CE be the sine of the arc CH, or of the angle COH, and of its supplement COA. The sine of a quadrant, or of a right angle, is equal to the radius. The sine of any arc is half the chord of twice that arc.

51. Acute-angled Triangle.—One having all three of its angles acute.

52. An Equilateral Triangle.—One having all the three sides equal.

53. Polygon.—A plane figure of many angles, and consequently of many sides; particularly, one whose perimeter consists of more than four sides.

54. Obtusangular Triangle.—If one of the angles of a triangle is obtuse, the triangle is called obtusangular or amblygonous.

55. Curvilinear and Spherical Triangles.—If the three sides of a triangle are all curves, the triangle is said to be curvilinear. If the sides are all arcs of great circles of the sphere, the triangle is said to be spherical.

56. Mixtilinear Triangle.—If some of the sides of a triangle are right and others curve, the triangle is said to be mixtilinear.

GEOMETRICAL CONSTRUCTIONS.*

1.

To divide a given line $A\ B$ into two equal parts; and to erect a perpendicular through the middle.

With the end A and B as centers, draw the dotted circle arcs with a radius greater than half the line. Through the crossings of the arcs draw the perpendicular $C\ D$, which divides the line into two equal parts.

2.

From a given point C on the line $A\ B$, erect a perpendicular $C\ D$.

With C as a center, draw the dotted circle arcs at A and B equal distances from C. With A and B as centers, draw the dotted circle arcs at D. From the crossing D draw the required perpendicular $D\ C$.

3.

From a given point C at a distance from the line $A\ B$, draw a perpendicular to the line.

With C as a center, draw the dotted circle arc so that it cuts the line at A and B. With A and B as centers, draw the dotted cross arcs at D with equal radii. Draw the required perpendicular through C and crossing D.

4.

At the end of A to a given line $A\ B$, erect a perpendicular $A\ C$.

With the point D as a center at a distance from the line, and with $A\ D$ as radius, draw the dotted circle arc so that it cuts the line at E through E and D, draw the diameter $E\ C$; then join C and A, which will be the required perpendicular.

5.
Through a given point C at a distance from the line $A\ B$, draw a line $C\ D$ parallel to $A\ B$.
With C as a center, draw the dotted arc $E\ D$, with E as a center, draw through C the dotted arc F. C. With the radius $F\ C$ and E as a center, draw the cross arc at D. Join C with the cross at D, which will be the required parallel line.

6.
On a given line $A\ B$ and at the point B, construct an angle equal to the angle $C\ D\ E$.
With D as a center, draw the dotted arc $C\ E$; and with the same radius and B as a center, draw the arc $G\ F$; then make $G\ F$ equal to $C\ E$; then join $B\ F$, which will form the required angle, $F\ B\ G = C\ D\ E$.

7.
Divide the angle $A\ C\ B$ into two equal parts.
With C as a center, draw the dotted arc $D\ E$; with D and E as centers, draw the cross arcs at F with equal radii. Join $C\ F$, which divides the angle into the required parts.
Angles $A\ C\ F = F\ C\ B = \frac{1}{2}(A\ C\ B)$.

8.
Divide an angle into two equal parts, when the lines do not extend to a meeting point.
Draw the lines $C\ D$ and $C\ E$ parallel, and at equal distances from the lines $A\ B$ and $F\ G$. With C as a center, draw the dotted arc $B\ G$; and with B and G as centers, draw the cross arcs H. Join $C\ H$, which divides the angle into the required equal parts.

9.
To construct a parallelogram, with the given sides A and B and angle C.
Draw the base line $D\ E$, and make the angle $F\ D\ E = C$; lines $D\ E = B$ and $D\ F = A$; complete the parallelogram by cross arcs at G, and the problem is thus solved.

10.
To divide the line $A\ B$ in the same proportion of parts as $A\ C$.
Join C and B, and through the given divisions 1, 2, and 3 draw lines parallel with $C\ B$, which solves the problem.

11.
To find the center of a circle which will pass through three given points A, B, and C.
With B as a center, draw the arc $D\ E\ F\ G$; and with the same radius and A as a center, draw the cross arcs D and F; also with C as a center, draw the cross arcs E and G. Join D and F, and also E and G, and the crossing o is the required center of the circle.

12.
To construct a square upon a given line $A\ B$.
With $A\ B$ as radius and A and B as centers, draw the circle arcs $A\ E\ D$ and $B\ E\ C$. Divide the arc $B\ E$ in two equal parts at F, and with $E\ F$ as radius, and E as center, draw the circle $C\ F\ D$. Join A and $C\ B$ and D, C and D, which completes the required square.

13.
Through a given point A in a circumference, draw a tangent to the circle.
Through a given point A and center C, draw the line $B\ C$. With A as a center, draw the circle arcs B and C; with B and C as centers, draw the cross arcs D and E; then join D and E, which is the required tangent.

14.
From a given point A outside of a circumference, draw a tangent to the circle.
Join A and C, and upon $A\ C$ as a diameter draw the half circle $A\ B\ C$, which cuts the given circle at B. Join A and B, which is the required tangent.

15.
To draw a circle with a given radius R, that will tangent the circle $A\ B\ C$ at C.
Through the given point C, draw the diameter $A\ C$ extended beyond D; from C set off the given radius R to D; then D is the center of the required circle, which tangents the given circle at C.

16.
To draw a circle with a given radius R, that will tangent two given circles.
Join the centers A and B of the given circles Add the given radius R to each of the radii of the given circle, and draw the cross arcs C, which is the center of the circle required to tangent the other two.

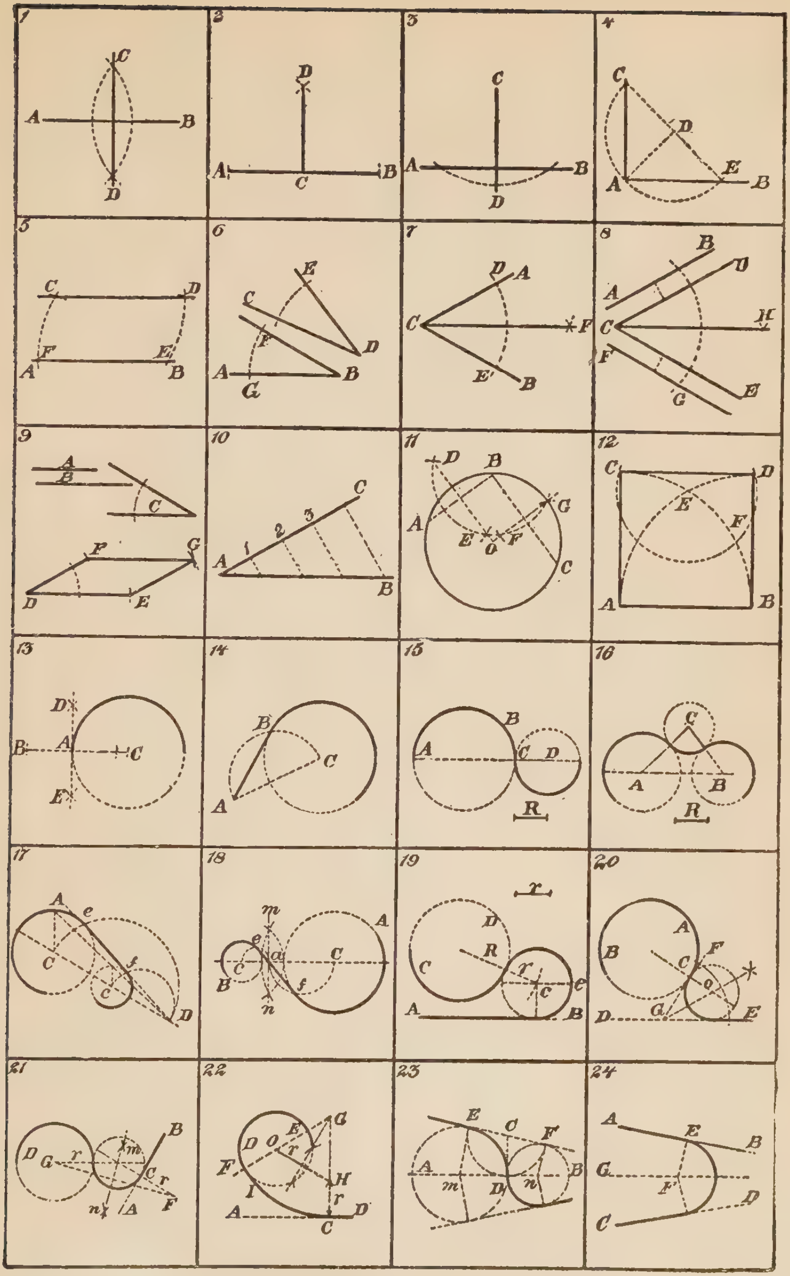
17.
To draw a tangent to two circles of different diameters.
Join the centers C and c of the given circles, and extend the line to D; draw the radii $A\ C$ and $a\ c$ parallel with one another. Join $A\ a$, and extend the line to D. On $C\ D$ as a diameter, draw the half circle $C\ e\ D$; on $c\ D$ as a diameter, draw the half circle $c\ f\ D$; then the crossings e and f are the tangenting points of the circles.

18.
To draw a tangent between two circles.
Join the centers C and c of the given circles; draw the dotted circle arcs, and join the crossing m, n, which line cuts the center line at a. With $a\ C$ as a diameter, draw the half circle $a\ f\ C$; and with $a\ c$ as a diameter, draw the half circle $c\ e\ a$; then the crossings e and f are the tangenting points of the circles.

19.
With a given radius r, draw a circle that will tangent the given line $A\ B$ and the given circle $C\ D$.
Add the given radius r to the radius R of the circle, and draw the arc $c\ d$. Draw the line $c\ e$ parallel with and at a distance r from the line $A\ B$. Then the crossing c is the center of the required circle that will tangent the given line and circle.

20.
To find the center and radius of a circle that will tangent the given circle $A\ B$ at C, and the line $D\ E$.
Through the given point C, draw the tangent $G\ F$; bisect the angle $F\ G\ E$; then o is the center of the required circle that will tangent $A\ B$ at C, and the line $D\ E$.

21.
To find the center and radius of a circle that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9 A B C F G D E
10 C 3 2 1 A B
11 D B A G E O F C
12 C D E F A B
13 D B A C E
14 B C A
15 B A C D R
16 C A B R
17 A e C f c D
18 m A e a C c B f n
19 r D R C r e c A B
20 A B F C o D G E
21 B D G r m C r n A F
22 G E D O r F H I r A D C
23 E O F A B m D n
24 A E B G F D C

will tangent the given line $A\ B$ at C, and the circle $D\ E$.

Through the point C, draw the line $E\ F$ at right angles to $A\ B$; set off from C the radius r of the given circle. Join G and F. With G and F as centers draw the arc crosses m and n. Join $m\ n$, and where it crosses the line $E\ F$ is the center for the required circles.

22.

To find the center and radius of a circle that will tangent the given line $A\ B$ at C, and the circle $D\ E$.

From C, erect the perpendicular $C\ G$; set off the given radius r from C to H. With H as a center and r as radius, draw the cross arcs on the circle. Through the cross arcs draw the line $I\ G$; then G is the center of the circle arc $F\ I\ C$, which tangents the line at C and the circle at F.

23.

Between two given lines, draw two circles that will tangent themselves and the lines.

Draw the center line $A\ B$ between the given lines; assume D to be the tangenting point of the circles; draw $D\ C$ at right angles to $A\ B$. With C as center and $C\ D$ as radius, draw the circle $E\ D\ F$. From E, draw $E\ m$ at right angles to $E\ F$; and from F draw $F\ m$ at right angles to $F\ E$; then m and n are the centers for the required circles.

24.

Draw a circle that will tangent two given lines $A\ B$ and $C\ D$ inclined to one another and the one tangenting point E being given.

Draw the center line $G\ F$. From E, draw $E\ F$ at right angles to $A\ B$; then F is the center of the circle required.

25.

Draw a circle that will tangent two lines and go through a given point C on the line $F\ C$, which bisects the angle of the lines.

Through C draw $A\ B$ at right angles to $C\ F$; bisect the angles $D\ A\ B$ and $E\ B\ A$, and the crossing on $C\ F$ is the center of the required circle.

26.

To draw a *cyma*, or two circle arcs that will tangent themselves, and two parallel lines at given points A and B.

Join A and B; divide $A\ B$ into four equal parts and erect perpendiculars. Draw $A\ m$ at right angles from A, and $B\ n$ at right angles from B; then m and n are the centers of the circle arcs of the required *cyma*.

27.

To draw a *talon*, or two circle arcs, that will tangent themselves, and meet two parallel lines at right angles in the given points A and B.

Join A and B; divide $A\ B$ into four equal parts and erect perpendiculars; then m and n are the centers of the circle arcs of the required *talon*.

28.

To plot out a circle arc without recourse to its center, but its chord $A\ B$ and height h being given.

With the chord as radius, and A and B as centers, draw the dotted circle arcs $A\ C$ and $B\ D$. Through the point O draw the lines $A\ O\ o$ and $B\ O\ o$. Make the arcs $C\ o = A\ o$ and $D\ o = B\ o$. Divide these arcs into any desired number of equal parts, and number them as shown on the illustration. Join A and B with the divisions, and the crossings of equal numbers are points in the circle arc.

29.

To find the center and radius of a circle that will tangent the three sides of a triangle.

Bisect two of the angles in the triangle, and the crossing C is the center of the required circle.

30.

To inscribe an equilateral triangle in a circle.

With the radius of the circle and center C draw the arc $D\ F\ E$; with the same radius, and D and E as centers, set off the points A and B. Join A and B, B and C, C and A, which will be the required triangle.

31.

To inscribe a square in a given circle.

Draw the diameter $A\ B$, and through the center erect the perpendicular C D, and complete the square as shown in the illustration.

32.

To describe a square about a given circle.

Draw the diameters $A\ B$ and $C\ D$ at right angles to one another; with the radius of the circle, and A, B, C, and D as centers, draw the four dotted half circles which cross one another in the corners of the square, and thus complete the problem.

33.

To inscribe a *pentagon* in a given circle.

Draw the diameter $A\ B$, and from the center C erect the perpendicular $C\ D$. Bisect the radius $A\ C$ at E; with E as center, and $D\ E$ as radius, draw the arc $D\ E$, and the straight line $D\ F$ is the length of the side of the pentagon.

34.

To construct a *pentagon* on a given line $A\ B$.

From B erect $B\ C$ perpendicular to and half the length of $A\ B$; join A and C prolonged to D; with C as a center and $C\ B$ as radius, draw the arc $B\ D$; then the chord $B\ B$ is the radius of the circle circumscribing the pentagon. With A and B as centers, and $B\ D$ as radius, draw the cross O in the center.

35.

To construct a pentagon on a given line $A\ B$ without resort to its center.

From B erect $B\ o$ perpendicular and equal to $A\ B$; with C as center and $C\ o$ as radius, draw the arc $D\ o$; then $A\ D$ is the diagonal of the pentagon. With $A\ D$ as radius and A as center, draw the arc $D\ E$; and with E as center and $A\ B$ as radius, finish the cross E, and thus complete the pentagon.

36.

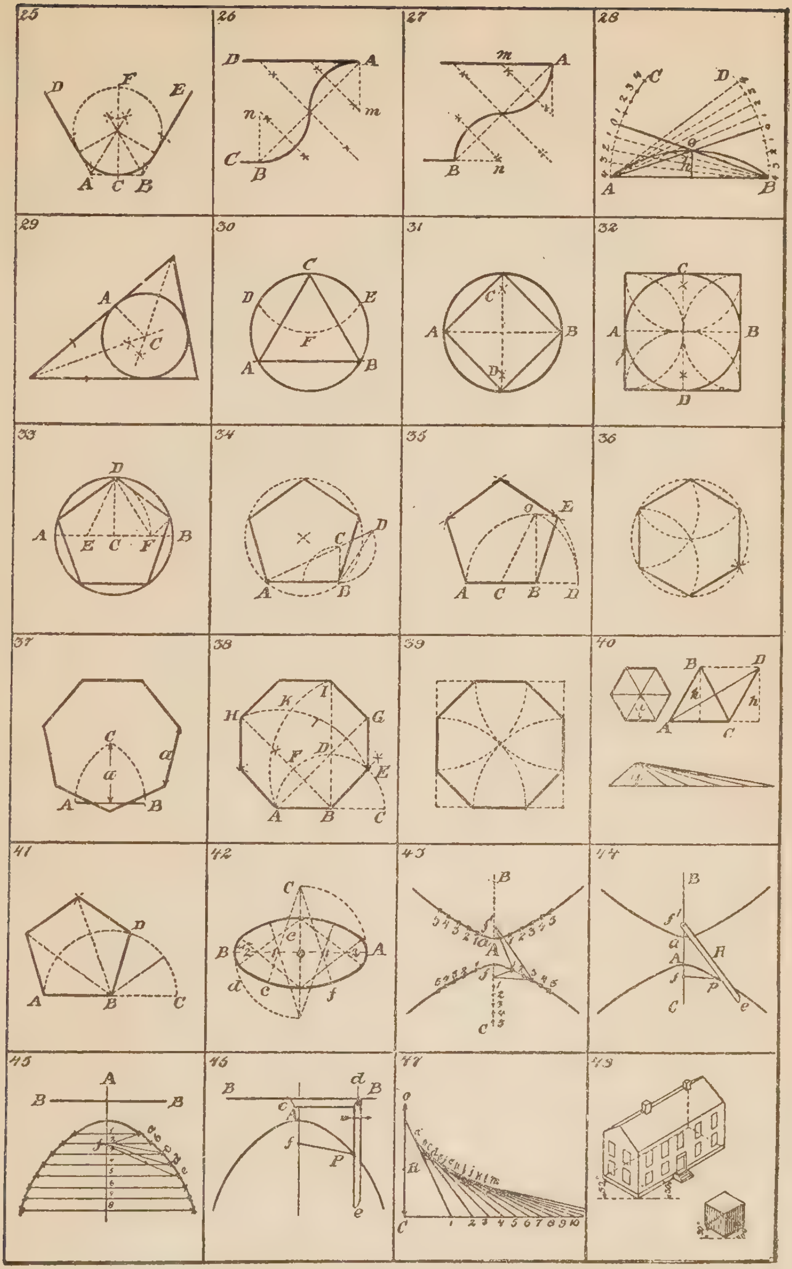
To construct a *hexagon* in a given circle.

The radius of the circle is equal to the side of the hexagon.

37.

To construct a Heptagon.

The appotem a in a hexagon is the length of the side of the heptagon.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Set off $A\ B$ equal to the radius of the circle; draw a from the center C at right angles to $A\ B$; then a is the required side of the heptagon.

38.
To construct an *octagon* on the given line $A\ B$.
Prolong $A\ B$ to C. With B as center and $A\ B$ as radius, draw the circle $A\ F\ D\ E\ C$; from B, draw $B\ I$ at right angles to $A\ B$; divide the angles $A\ B\ D$ and $D\ B\ C$ each into two equal parts; then $B\ E$ is one side of the octagon. With A and E as centers, draw the arcs $H\ K\ E$ and $A\ K\ I$, which determine the points H and I, and thus complete the octagon as shown in the illustration.

39.
To cut off the corners of a square, so as to make of it a regular *octagon*.
With the corners as centers, draw circle arcs through the center of the square to the side, which determines the cut-off.

40.
The area of a regular polygon is equal to the area of a triangle whose base is equal to the sum of all the sides, and the height a equal to the appotem of the polygon.
The reason of this is that the area of two or more triangles $A\ B\ C$ and $A\ D\ C$ having a common or equal base b and equal height h are alike.

41.
To construct any regular *polygon* on a given line $A\ B$ without resort to its center.
Extend $A\ B$ to C and, with B as center, draw the half circle $A\ D\ B$. Divide the half circle into as many parts as the number of sides in the polygon, and complete the construction as shown on the illustration.

42.
To construct an isometric ellipse by compasess and six circle arcs.
Divide $O\ A$ and $O\ B$ each into three equal parts; draw the quadrant $A\ C$. From C, draw the line $C\ c$ through the point 1. Through the points 2 draw $d\ e$ at an angle of 45° with the major axis. Then 2 is the center for the ends of the ellipse; e is the center for the arc $d\ c$; and C is the center for the arc $c\ f$.

43.
To construct a Hyperbola by plotting,
Having given the transverse axis $B\ C$, vertexes $A\ a$, and foci $f\ f'$. Set off any desired number of parts on the axis below the focus, and number them 1, 2, 3, 4, 5, etc. Take the distance a 1 as radius, and, with f' as center, strike the cross 1 with $f'\ 1 = a\ 1$. With the distance A 1, and the focus f as center, strike the cross 1 with the radius $F\ 1 = A\ 1$, and the cross 1 is a point in the hyperbola.

44.
To draw an Hyperbola by a pencil and a string,
Having given the transverse axis $B\ C$, foci f' and f, and the vertexes A and a. Take a rule and fix it to a string at e; fix the other end of the string at the focus f. The length of the string should be such that when the rule R is in the position $f'C$, the loop of the string should reach to A; then move the rule on the focus f', and a pencil at P, stretching string, will trace the hyperbola.

45.
To construct a Parabola by plotting,
Having given the axis, vertex, and focus of the parabola. Divide the transverse axis into any desired number of parts 1, 2, 3, etc., and draw ordinates through the divisions; take the distance A 1, and set it off on the 1st ordinate from the focus f to a, so that $A\ 1 = f\ a$. Repeat the same operation with the other ordinates—that is, set off the distance A 5 from f to e, so that $A\ 5 = f\ e$; and so the parabola is constructed.

46.
To draw a Parabola with a pencil and a string,
Having given the two axes, vertex, and focus of the parabola. Take a square $c\ d\ e$, and fix to it a string at e; fix the other end of the string at the focus f. The length of the string should be such that when the square is in the position of the axis $A\ f$, the string should reach to the vertex A. Move the square along $B\ B$, and the pencil P will describe the parabola.

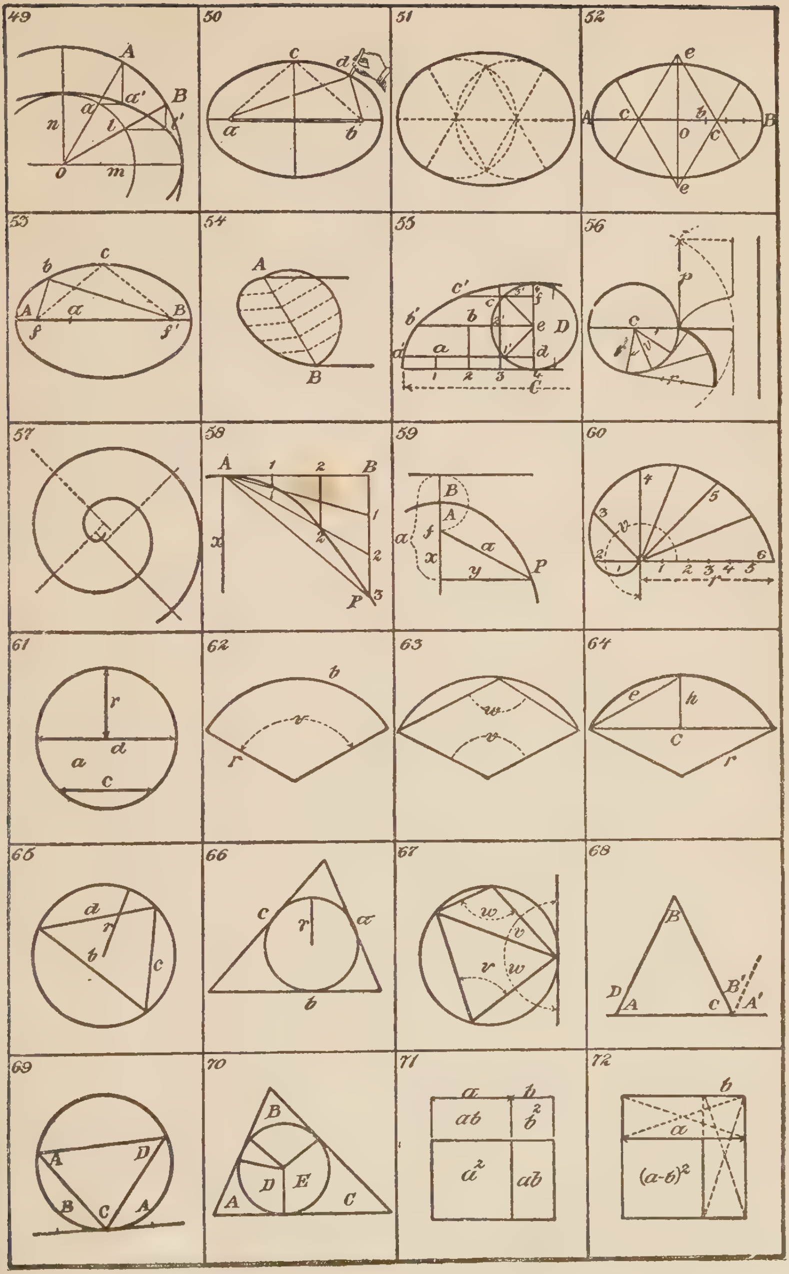
47.
Shield's anti-friction curve.
R represents the radius of the shaft, and C 1, 2, 3, etc., is the center line of the shaft. From o, set off the small distance $o\ a$; and set off $a\ 1 = R$. Set off the same small distance from a to b, and make $b\ 2 = R$. Continue in the same way with the other points, and the anti-friction curve is thus constructed.

48.
Isometric Perspective.
This kind of perspective admits of scale measurements the same as any ordinary drawing, and gives a clear representation of the object. It is easily learned. All horizontal rectangular lines are drawn at an angle of 30°.
All circles are ellipses of proportion, as shown in No. 42, on the following page.

49.
To construct an ellipse.
With a as a center, draw two concentric circles with diameters equal to the long and short axes of the desired ellipse. Draw from o any number of radii, A, B, etc. Draw a line $B\ b'$ parallel to n and $b\ b'$ parallel to m, then b is a point in the desired ellipse.

50.
To draw an ellipse with a string.
Having given the two axes, set off from c half the great axis at a and b, which are the two focuses of the ellipse. Take an endless string as long as the three sides in the triangle $a\ b\ c$, fix two pins or nails in the focuses, one in a and one in b, lay the string around a and b, stretch it with a pencil d, which then will describe the desired ellipse.

51.
To draw an ellipse by circle arcs.
Divide the long axis into three equal parts, draw the two circles, and where they intersect one another are the centers for the tangent arcs of the ellipse as shown by the figure.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52.

To draw an ellipse by circle arcs.

Given the two axes, set off the short axis from A to b, divide b into three equal parts, set off two of these parts from o towards c and c which are the centers for the ends of the ellipse. Make equilateral triangles on $c\,c$, when $e\,e$ will be the centers for the sides of the ellipse. If the long axis is more than twice the short one, this construction will not make a good ellipse.

53.

To construct an ellipse.

Given the two axes, set off half the long axis from c to $f\,f$, which will be the two focuses in the ellipse. Divide the long axis into any number of parts, say a to be a division point. Take $A\,a$ as radius and f as center and describe a circle arc about b, take $a\,B$ as radius and f as center describe another circle arc about b, then the intersection b is a point in the ellipse, and so the whole ellipse can be constructed.

54.

To draw an ellipse that will tangent two parallel lines in A and B.

Draw a semicircle on $A\ B$, draw ordinates in the circle at right angle to $A\ B$, the corresponding and equal ordinates for the ellipse to be drawn parallel to the lines, and thus the elliptic curve is obtained as shown by the figure.

55.

To construct a cycloid.

The circumference $C=3.14\ D$. Divide the rolling circle and base line C into a number of equal parts, draw through the division point the ordinates and abscissas, make $a\ a'=1\ d$, $b\ b'=2'e$, $c\ c=3\ f$, then $a\ b'$ and c' are points in the cycloid. In the *Epicycloid* and *Hypocycloid* the abscissas are circles and the ordinates are radii to one common center.

56.

Evolute of a circle.

Given the pitch p, the angle v, and radius r. Divide the angle v into a number of equal parts, draw the radii and tangents for each part, divide the pitch p into an equal number of equal parts, then the first tangent will be one part, second two parts, third three parts, etc., and so the *Evolute* is traced.

57.

To construct a spiral with compasses and four centers.

Given the pitch of the spiral, construct a square about the center, with the four sides together equal to the pitch. Prolong the sides in one direction as shown by the figure, the corners are the centers for each arc of the external angles.

58.

To construct a Parabola.

Given the vertex A, axis x, and a point P. Draw $A\ B$ at right angle to x, and $B\ P$ parallel to x, divide $A\ B$ and $B\ P$ into an equal number of equal parts. From the vertex A draw lines to the divisions on $B\ P$, from the divisions on $A\ B$ draw the ordinates parallel to x, the corresponding intersections are points in the *parabola.*

59.

To construct a Parabola.

Given the axis of ordinate B, and vertex A. Take A as a center and describe a semicircle from B which gives the focus of the *parabola* at f. Draw any ordinate y at right angle to the abscissa $A\ x$, take a as radius and the focus f as a center, then intersect the ordinate y, by a circle-arc in P which will be a point in the *parabola.* In the same manner the whole Parabola is constructed.

60.

To draw an arithmetic spiral.

Given the pitch p and angle v, divide them into an equal number of equal parts, say 6; make 0 1 = 0 1, 0 2 = 0 2, 0 3 = 0 3, 0 4 = 0 4, 0 5 = 0 5, and 0 6 = the pitch p; then join the points 1, 2, 3, 4, 5 and 6, which will form the spiral required.

THE CIRCLE.

Notation of Letters.

d = diameter of the circle.
r = radius of the circle.
p = periphery or circumference.
a = area of a circle or part thereof.
b = length of a circle arc.
c = chord of a segment, length of.
h = height of a segment.
s = side of a rectangular polygon
v = center angle.
w = polygon angle.

All measures must be expressed by the same unit.

FORMULAS FOR THE CIRCLE.

Periphery or Circumference.

$$p=\pi\ d=3.14d.$$

$$p=2\pi\ r=6.28r.$$

$$p=2\sqrt{\pi\ a}=3.54\sqrt{a}.$$

$$p=\frac{2a}{r}=\frac{4a}{d}.$$

Diameter and Radius.

$$d=\frac{p}{\pi}=\frac{p}{3.14}.$$

$$r=\frac{p}{2\pi}=\frac{p}{6.28}.$$

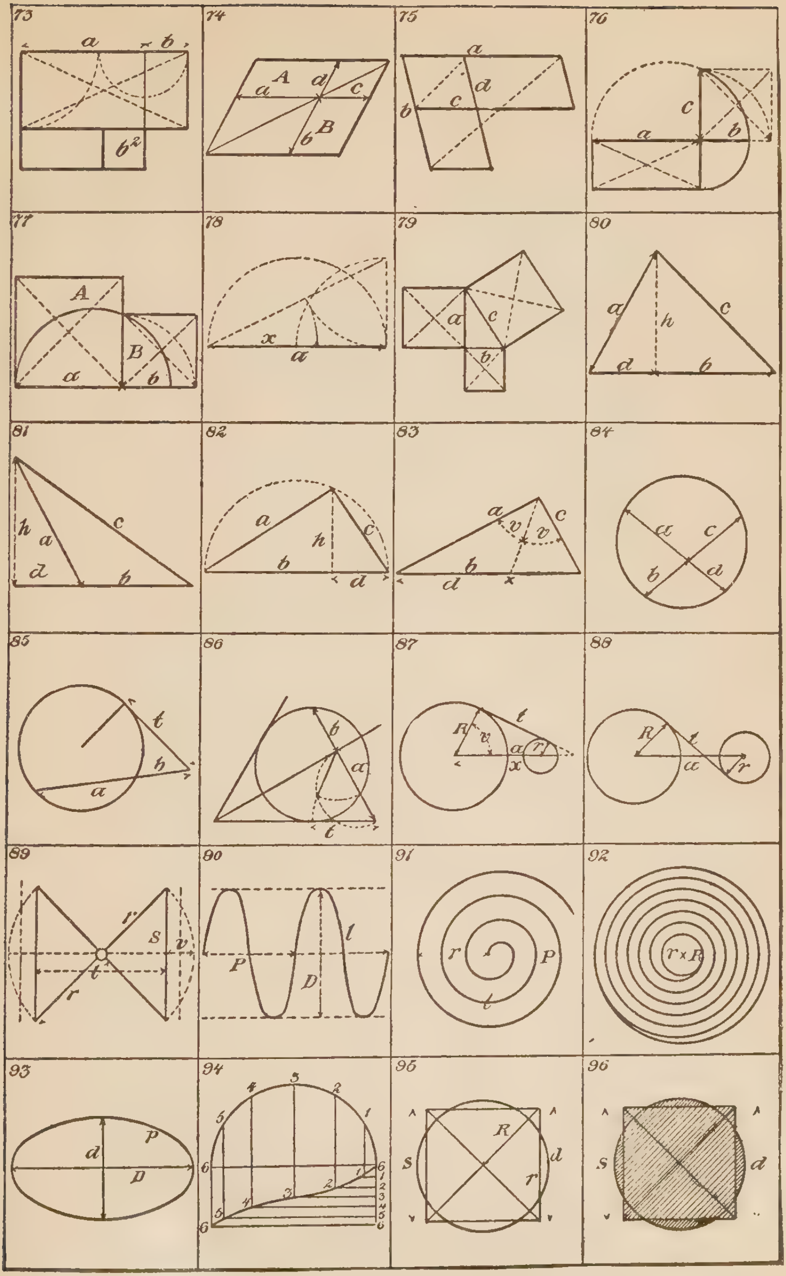
$$d=2\sqrt{\frac{a}{\pi}}=1.128\sqrt{a}$$

$$r=\sqrt{\frac{a}{\pi}}=0.564\sqrt{a}.$$

Area of the Circle.

$$a=\frac{\pi\ d^2}{4}=0.785d^2$$

$$a=\pi\ r^2=3.14r^2.$$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$$a=\frac{p^2}{4\pi}=\frac{p^2}{12.56}.$$
$$a=\frac{pr}{2}=\frac{pd}{4}.$$

$\pi=3.14159265358979323846264338327950288$
4197169399

$2\pi=6.283185$
$3\pi=9.424778$
$4\pi=12.566370$
$5\pi=15.707963$
$6\pi=18.849556$
$7\pi=21.991148$
$8\pi=25.132741$
$9\pi=28.274334$
$\frac{1}{4}\pi=0.785398$
$\frac{1}{3}\pi=1.047197$
$\frac{1}{2}\pi=1.570796$
$\frac{1}{8}\pi=0.392699$
$\frac{1}{6}\pi=0.523599$
$\frac{1}{12}\pi=0.261799$
$\frac{2}{3}\pi=2.094394$
$\frac{1}{360}\pi=0.008726$
$\frac{1}{\pi}=0.318310$
$\frac{2}{\pi}=0.636619$
$\frac{3}{\pi}=0.954929$
$\frac{4}{\pi}=1.273239$
$\frac{6}{\pi}=1.909859$
$\frac{8}{\pi}=2.546478$
$\frac{12}{\pi}=3.819718$
$\frac{360}{\pi}=114.5915$
$\pi^2=9.869650$
$\sqrt{\pi}=1.772453$
$\sqrt{\frac{1}{\pi}}=0.564189$
$\sqrt{\frac{\pi}{2}}=1.253314$
$\sqrt{\frac{2}{\pi}}=0.797884$
Log. $\pi=0.49714987$

61.
The periphery of a Circle is commonly expressed by the *Greek* letter $\pi=3.14$ when the diameter $d=1$ or the unit. For any other value of the diameter d, we will denote the periphery by the letter p, r=radius, and a= area of the circle. The periphery of a circle is equal to 3 14-100 times its diameter. c=chord.

62.
$$b=\frac{\pi r v}{180}=0.0175rv,$$
$$v=\frac{180b}{\pi r}=57.296\frac{b}{r}.$$

63.
$$w=180-\frac{v}{2},$$
$$v=2(180^\circ-w).$$

64.
$$r=\frac{c^2+4h^2}{8h}=\frac{e^2}{2h},$$
$$c=2\sqrt{2hr-h^2}.$$

65.
$$r=\frac{ac}{2\sqrt{a^2-\left(\frac{a^2+b^2-c^2}{2b}\right)^2}}.$$

66.
$$r=\frac{b\sqrt{a^2-\left(\frac{a^2+b^2-c^2}{2b}\right)^2}}{a+b+c}$$

67.
$$v=v,\quad w=w,$$
$$w+v=180^\circ,\ w>v.$$

68.
$$D=B+C,\quad A'+B'+C=180^\circ,$$
$$B=D-C,\quad A+B+C=180^\circ,$$
$$A'=A,\quad B'=B.$$

69.
$$A+B+C=180^\circ,$$
$$A'=A,\quad B'=B.$$

70.
$$E+C=A+D=180^\circ,$$
$$D=B+c,$$
$$E=A+B.$$

71.
$$(a+b)^2=a^2+2ab+b^2.$$

72.
$$(a-b)^2=a^2-2ab+b^2.$$

73.
$$(a+b)\ (a-b)=a^2-b^2.$$

74.
$$a:b=c:d,$$
$$ad=bc,$$
$$A=B.$$

75.
$a : b = c : d,$
$ad = bc.$

76.
$a : c = c : b,$
$ab = c^2,$
$c = \sqrt{ab}.$

77.
$A : B = a : b.$

78.
$a : x = x : a - x,$
$$x = \sqrt{a^2 + \left(\frac{a}{2}\right)^2} - \frac{a}{2}$$

79.
$c^2 = a^2 + b^2,$
$a^2 = c^2 - b^2,$
$b^2 = c^2 - a^2.$

80.
$c^2 = a^2 + b^2 - 2bd,$
$h = \sqrt{a^2 - d^2}.$
$$d = \frac{a^2 + b^2 - c^2}{2b}$$

81.
$c^2 = a^2 + b^2 + 2bd,$
$h^2 = \sqrt{a^2 - d^2},$
$$d = \frac{c^2 - a^2 - b^2}{2b}.$$

82.
$a : b = h : c,$
$$h = \frac{ac}{b} = \frac{ad}{c},$$
$$d = \frac{c^2}{b} = \frac{ch}{a}.$$

83.
$a : c = d : (b - d),$
$$d = \frac{ab}{c + a},$$
$v = v.$

84.
$a : c = b : d,$
$ad = bc.$

85.
$a : t = t : b,$
$t^2 = ab.$

86.
$t^2 = (a + b)\ (a - b),$
$= \sqrt{a^2 - b^2}.$

87.
$$x = \frac{aR}{R - r},\quad a = \sqrt{t^2 + (R - r)^2},$$
$$t = \sqrt{a^2 - (R - r)^2},\quad \sin.v = \frac{t}{a}.$$

88.
$t = \sqrt{a^2 - (R + r)^2},$
$a = \sqrt{t^2 + (R + r)^2}.$

89.
$$V = r - \sqrt{r^2 - \frac{S^2}{4}}\qquad l = 2r - V,$$
$$S = 2\sqrt{r^2 - (r - V)^2}.\quad r = \tfrac{1}{2}(l + V).$$

90.
$$P = \sqrt{\frac{l^2}{n^2} - \pi^2 d^2},$$
$$l = n\sqrt{\pi^2 d^2 + P^2},$$
$$n = \frac{l}{\sqrt{\pi^2 d^2 + P.}}$$

91.
To find the length of a Spiral.
$$l = \pi r n = \frac{\pi r^2}{P},\quad n = \frac{l}{\pi r} = \frac{r}{P},$$
$$P = \frac{\pi r^2}{l} = \frac{r}{n}.\quad P = \textit{Pitch}.$$

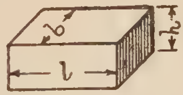
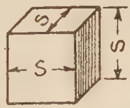
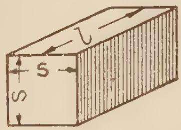
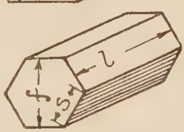
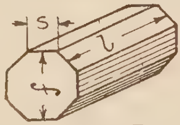
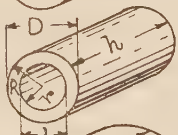
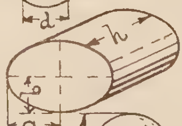
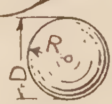
92.
To find the length of a Spiral.
$l = \pi\, n\, (R + r),$
$$l = \frac{\pi}{P}(R^2 - r^2).$$

93.
Periphery of an Ellipse.
$p = 2\sqrt{D2 + 1.4674d^2}.$

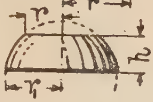
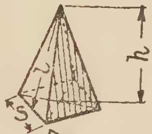
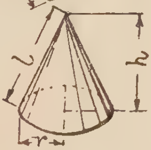
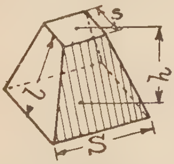
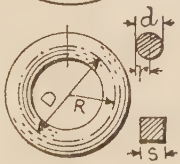
94.
To construct a screw *Helix*.

95.
To square a Circumference.
$R = 0.555355\ d = 1.1107\ r = 0.7071\ S.$
$S = 0.785398\ d = 1.57079\ r = 1.4142\ R$
$d = 1.27322\ S = 1.79740\ R = 2r.$

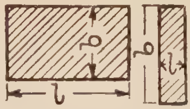
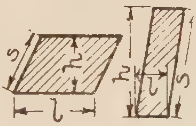
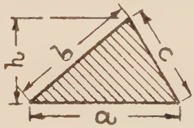
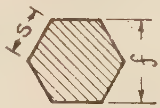
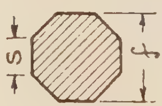
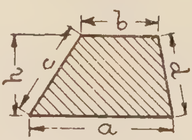
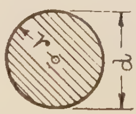
96.
To square a Circleplane.
$R = 0.626657\ d = 1.253314\ r = 0.7071\ S$
$S = 0.886226\ d = 1.77245\ r = 1.4142\ R$
$d = 1.12838\ S = 1.5367\ R = 2\ r$

Title.	Figure.	Volume.	Surface Area.
Any prism .		Area of base × height	Circumference of base × height
Rectangular prism or cuboid . .		ibh	Whole area $= 2(lb+lh+bh)$
Cube . . .		S^3	Whole area $= 6S^2$
Square prism		S^2l	Lateral surface $= 4Sl$ Ends $= 2S^2$ Whole surface $= 2S(2l+S)$
Hexagonal prism . .		$2{\cdot}6S^2l$ or $\cdot866f^2l$	Lateral $= 6Sl$ or $3{\cdot}46fl$ (For ends see Table in Chap. VII.)
Octagonal prism . .		$4{\cdot}83S^2l$ or $\cdot829f^2l$	Lateral $= 8Sl$ or $3\ 32fl$
Cylinder . .		πr^2h or $\cdot7854d^2h$	Lateral $= 2\pi rh$ Two ends $= 2\pi r^2$ Whole area $= 2\pi r(h+r)$
Hollow cylinder . .		$\pi(R^2 - r^2)h$	Outer lateral surface $= 2\pi Rh$ Inner lateral surface $= 2\pi rh$
Elliptical prism . .		$\pi : bh$	Lateral $= \pi h\{1{\cdot}5(a+b) - \sqrt{ab}\}$ or $\pi(a+b)h$ (less accurate)
Sphere . .		$\frac{4}{3}\pi R^3$ or $\frac{\pi}{6}D^3$ (or $\cdot5236D^3$)	$4\pi R^2$
Hollow sphere . .		$\frac{4}{3}\pi(R^3 - r^3)$	$4\pi(R^2 + r^2)$

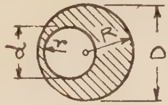
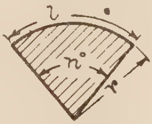
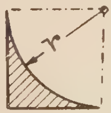
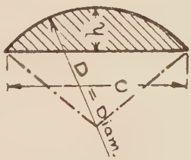
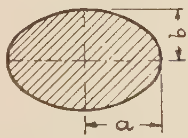
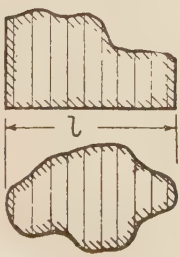
—From Clapham's Arithmetic for Engineers.

Title.	Figure.	Volume.	Surface Area.
Segment of sphere . .		$\frac{\pi h}{6}(3r^2 + h^2)$ or $\cdot 5236h(3r^2+h^2)$	Curved surface $= 2\pi Rh$ or $\cdot 2\pi R(R - \sqrt{R^2 - r^2})$ where R=rad. of sphere
Zone of sphere . .		$\frac{\pi h}{6}\left\{3(r^2+r_1^2)+h^2\right\}$	
Any pyramid		$\frac{1}{3}$ area of base $\times$ height	Lateral $= \frac{1}{2}$ circum. of base $\times$ slant height
Square pyramid . . .		$\frac{1}{3}S^2h$	Lateral $= 2Sl$
Cone . . .		$\frac{1}{3}\pi r^2 h$	Lateral $= \pi rl$
Frustum of any pyramid . . .	h=height of frustum A=area of large end a=area of small end	$\frac{h}{3}(A + a + \sqrt{Aa})$	Lateral$=\frac{1}{2}$ mean circum. $\times$ slant height
Frustum of square pyramid .		$\frac{h}{3}(S^2 + s^2 + Ss)$	Lateral $= 2l(S + s)$ (l = slant height)
Frustum of cone . . .		$\frac{\pi h}{3}(R^2 + r^2 + Rr)$	Lateral $= \pi l(R + r)$ (l = slant height)
Anchor ring .		Round section $2\pi^2Rr^2$ Square section πDS^2	$4\pi^2Rr$ $4\pi DS$

—From Clapham's Arithmetic for Engineers.

Title.	Figure.	Circumference or Perimeter.	Area.
Rectangle		$2(l + b)$	lb
Square . .		$4s$	s^2 or $\frac{d^2}{2}$
Rhomboid .		$2(l + s)$	lh
Triangle . .		$a + b + c$ $s = \frac{1}{2}$ perimeter	$\frac{ah}{2}$ or $\sqrt{s(s-a)(s-b)(s-c)}$
Equilateral triangle .		$3s$	$\cdot433s^2$
Hexagon . .		$6s$ or $3\cdot46f$	$2\cdot6s^2$ or $\cdot866f^2$
Octagon . .		$8s$ or $3\cdot32f$	$4\cdot83s^2$ or $\cdot829f^2$
Trapezoid .		$a + b + c + d$	$h\left(\frac{a+b}{2}\right)$
Irregular quadrilateral or trapezium . .		Sum of all four sides.	Divide into two triangles by either diagonal. Find area of each triangle and add. Or area $= \frac{lh}{2}$
Circle . . .		πd or $2\pi r$	$\frac{\pi}{4}d^2 = \cdot7854d^2$ or $\pi r^2 = 3\cdot142r^2$

—From Clapham's Arithmetic for Engineers.

Title.	Figure.	Circumference or Perimeter.	Area.
Hollow circle (annulus) .			$\frac{\pi}{4}(D^2-d^2) = \cdot 7854(D^2-d^2)$ or $\pi(R^2-r^2)$ or $\pi \times$ mean dia. $\times$ thickness
Hollow circle (eccentric)			$\cdot 7854(D^2-d^2)$ or $\pi(R^2-r^2)$
Sector of circle . .		$l = \frac{rn}{57 \cdot 3}$	$\frac{\pi n r^2}{360}$ or $\frac{lr}{2}$
Sector of hollow circle			$\frac{\pi n(R^2-r^2)}{360}$
Fillet . . .			$\cdot 215r^2$ or approx. $\frac{1}{5}r^2$
Segment of circle .			Area = sector − triangle Various approx. formulæ on p. 300.
Ellipse . .		$\pi(a+b)$ approx. or $\pi\{1 \cdot 5(a+b) - \sqrt{ab}\}$ more nearly	πab
Irregular figures . .		Step round curved portions in small steps, with dividers; add in any straight pieces.	Divide into narrow strips; measure their mid-ordinates. Then— Area = aver. mid-ordinate $\times$ length l

—From Clapham's Arithmetic for Engineers.

CHAPTER IV.

WEIGHTS AND MEASURES

LINEAR MEASURE.

3 barleycorns, or	1 inch (in.)
12 lines, or	
72 points, or	
1,000 mils (mi.)	
3 inches	1 palm
4 inches	1 hand
9 inches	1 span
12 inches	1 foot (ft.)
18 inches	1 cubit
3 feet	1 yard (yd.)
2½ feet	1 military pace
5 feet	1 geometrical pace
2 yards	1 fathom
5½ yards	1 rod, pole, or perch
66 feet, or	1 Gunter's chain
4 rods	
40 poles, or	1 furlong (fur.)
220 yards	
8 furlongs, or	1 mile
1,760 yards, or	
5,280 feet	
3 miles	1 league

The hand is used to measure horses' height. The military pace is the length of the ordinary step of a man. One thousand geometrical paces were reckoned to a mile.

LAND MEASURE (LINEAR).

7.92 inches	1 link
100 links, or	1 chain (ch.)
66 feet, or	
22 yards, or	
4 poles	
10 chains	1 furlong (fur.)
80 chains, or	1 mile
8 furlongs	

LAND MEASURE (SQUARE).

144 sq. inches	1 square foot (sq. ft.)
9 square feet	1 square yard (sq. yd.)
30¼ sq. yards	1 sq. pole, rod, or perch
16 sq. poles	1 square chain (sq. ch.)
40 sq. poles, or	1 sq. rood
1,210 sq. yards	
4 roods, or	1 acre *
10 sq. chs., or	
160 sq. poles, or	
4,840 sq. yds., or	
43,560 sq. ft	
640 acres, or	1 sq. mile
3,097,600 sq. yds	
30 acres	1 yard of land
100 acres	1 hide of land
40 hides	1 barony

CUBIC MEASURE.

1,728 cubic inches	1 cubic foot
27 cubic feet	1 cubic or solid yard

* The side of a square having an area of an acre is equal to 69.57 linear yards.

GEOGRAPHICAL AND NAUTICAL MEASURE.

6086.44	feet, or	= 1 nautical mile
1000	fathoms, or	
10	cables, or	
1.1528	statute miles	
1	nautical mile per hour	= 1 knot
60	nautical miles, or	= 1 degree
67.168	statute miles	
360	degrees	= 1 circumference of the earth at the equator
1	league	= 3 nautic'l miles
1	cable's length	= 120 fathoms

DRY MEASURE, U. S.

		Cu. In.
2 pints	1 quart (qt.)	= 67.20
4 quarts	1 gallon (gal.)	= 268.80
2 gallons, or	1 peck	= 537.60
8 quarts		
4 pecks	1 struck bushel	= 2150.42

LIQUID MEASURE, U. S.

		Cu. In.
4 gills	1 pint (O.)	= 28.875
2 pints	1 quart (qt.)	= 57.75
4 quarts	1 gallon (gal.)	= 231.
63 gallons	1 hogshead (hhd.)	
2 hogsheads	1 pipe or butt	
2 pipes	1 tun	

APOTHECARIES' LIQUID MEASURE.

Apothecaries' or Wine Measure is used by pharmacists of this country. Its denominations are gallon, pint, fluid ounce, fluid drachm, and minim, as follows:

Cong.		O.		F. Oz.		F. Dr.		Minims.
1	=	8	=	128	=	1,024	=	61,440
		1	=	16	=	128	=	7,680
				1	=	8	=	480
						1	=	60
								1

The Imperial Standard Measure is used by British pharmacists. Its denominations and their relative value are:

Gal.		Quarts.		Pints.		F. Oz.		F. Dr.		Minims.
1	=	4	=	8	=	160	=	1,280	=	76,800
		1	=	2	=	40	=	320	=	19,200
				1	=	20	=	160	=	9,600
						1	=	8	=	480
								1	=	60

The relative value of United States Apothecaries' and British Imperial Measures is as follows:

U. S. Apothecaries' Measure.	Imperial Measure.	Pints.	F. Oz.	F. Dr.	Minims
1 Gallon =	.83311 Gallon, or	6	13	2	22.85
1 Pint =	.83311 Pint, or		16	5	17.86
1 Fl. Oz. =	1.04139 Fl. Oz., or		1	0	19.86
1 Fl. Dr. =	1.04139 Fl. Dr., or			1	2.48
1 Minim =	1.04139 Minim, or				1.04

OLD WINE AND SPIRIT MEASURE.

			Imperial Gals.
4 gills or quarterns	1 pint		
2 pints	1 quart		
4 quarts (231 cu. in.)	1 gallon	=	.8333
10 gallons	1 anchor	=	8.333
18 gallons	1 bunlet	=	15
$31\frac{1}{2}$ gallons	1 barrel	=	26.25
42 gallons	1 tierce	=	35
63 gallons, or 2 barrels	1 hogshead	=	52.5
84 gallons, or $1\frac{1}{3}$ hogsheads	1 puncheon	=	70
126 gallons, or 2 hogsheads or $1\frac{1}{2}$ puncheons	1 pipe or butt	=	105
2 pipes or 3 puncheons	1 tun	=	210

Apothecaries' Weight is the officinal standard of the United States Pharmacopœia. In buying and selling medicines not ordered by prescriptions avoirdupois weight is used.

Lb.		Oz.		Dr.		Scr.		Gr.
1	=	12	=	96	=	288	=	5760
		1		8	=	24	=	480
				1	=	3	=	60
						1	=	20

Avoirdupois Weight.—Used for weighing all goods except those for which troy and apothecaries' weight are employed.

Gross or Long Ton.		Cwt.		Qr.		Lb.		Oz.		Dr.
1	=	20	=	80	=	2,240	=	35,840	=	573,440
		1	=	4	=	112	=	1,792	=	28,672
				1	=	28	=	448	=	7,168
						1	=	16	=	256
								1	=	16

Short or Net Ton.		Cwt.		Qr.		Lb.		Oz.		Dr.
1	=	20	=	80	=	2,000	=	32,000	=	512,000
		1	=	4	=	100	=	1,600	=	25,600
				1	=	25	=	400	=	6,400
						1	=	16	=	256
								1	=	16

The "short" ton of 2,000 lbs. is used commonly in the United States. The British or "long" ton, used to some extent in the United States, contains 2,240 lbs., corresponding to a cwt. of 112 and a quarter of 28 lbs.

Troy Weight.—Used by jewelers and at the mints, in the exchange of the precious metals.

Lb.		Oz.		Dwt.		Gr.
1	=	12	=	240	=	5760
		1	=	20	=	480
				1	=	24

7000 troy grains	=	1 lb. avoirdupois.
175 troy pounds	=	144 lb. avoirdupois.
175 troy ounces	=	192 oz. avoirdupois.
$437\frac{1}{2}$ troy grains	=	1 oz. avoirdupois.
1 troy pound	=	.8228+ lb. avoirdupois.

The common standard of weight by which the relative values of these systems are compared is the grain, which for this purpose may be regarded as the unit of weight. The pound troy and that of apothecaries' weight have each five thousand seven hundred and sixty grains; the pound avoirdupois has seven thousand grains.

The relative proportions and values of these several systems are as follows:

Troy.	Avoirdupois. Oz.	Dr.
1 pound equals	13	2.65
1 ounce equals	1	1.55
1 dwt. equals	0	0.877

Troy.	Apothecaries'. Lb.	Oz.	Dr.	Scr.	Gr.
1 pound equals	1	0	0	0	0
1 ounce equals	0	1	0	0	0
1 dwt. equals	0	0	0	1	4
1 grain equals	0	0	0	0	1

Apothecaries'.	Avoirdupois. Oz.	Dr.
1 pound equals	13	2.65
1 ounce equals	1	1.55
1 drachm equals	0	2.19
1 scruple equals	0	0.73

Apothecaries'.	Troy. Lb.	Oz.	Dwt.	Gr.
1 pound equals	1	0	0	0
1 ounce equals	0	1	0	0
1 drachm equals	0	0	2	12
1 scruple equals	0	0	0	20

Avoirdupois.	Troy. Lb.	Oz.	Dwt.	Gr.
1 long ton equals	2722	2	13	8
1 cwt. equals	136	1	6	16
1 quarter equals	34	0	6	16
1 pound equals	1	2	11	16
1 ounce equals	...	0	18	$5\frac{1}{2}$
1 drachm equals	...	0	1	$3\frac{11}{32}$

Avoirdupois.	Troy. Lb.	Oz.	Dwt.	Gr.
1 short ton equals	2430	6	13	8
1 cwt. equals	121	6	6	16
1 quarter equals	30	4	11	16

Avoirdupois.	Apothecaries'. Lb.	Oz.	Dr.	Scr.	Gr.
1 pound equals	1	2	4	2	0
1 ounce equals	0	0	7	0	$17\frac{1}{2}$
1 drachm equals	0	0	0	1	$7\frac{11}{32}$

DIAMOND MEASURE.

16 parts = 1 grain = 0.8 troy grains.
4 grains = 1 carat = 3.2 troy grains.

HOUSEHOLD MEASURES.—Nothing is more vague and inaccurate than such expressions as: "A cupful, a wineglass." An attempt has been made to reduce these measures to some scale. In these liquid measures the glass is supposed to be filled $\frac{1}{8}$ inch from the top. A "wineglass" is very apt to be a claret glass. If the diameter is $2\frac{3}{4}$ inches and the depth $2\frac{1}{8}$ inches from rim to bottom, the glass will hold $3\frac{1}{2}$ fl. oz. = 105 cubic centimeters. A sherry glass is also a common wine glass and is flaring. If its top is $2\frac{1}{4}$ inches in diameter it should hold $1\frac{1}{2}$ fl. oz., or 45 cubic centimeters, A liquor glass, usually called a whiskey glass, varies greatly, but if 3 inches high and $2\frac{1}{4}$ inches in diameter and slightly flaring it holds 4 fl. oz., or 120 cubic centimeters. A cocktail glass is peculiar; the diameter of the "Union League" model is $2\frac{1}{4}$ inches, depth $1\frac{3}{4}$ inch, round flare, holds 2 fl. oz. = 60 cubic centimeters. A "liqueur" glass having a diameter of $1\frac{1}{8}$ inches, $2\frac{1}{8}$ inches deep, flaring sides, holds $\frac{2}{3}$ of a fluid ounce, or 20 cubic centimeters. A straight-sided soda glass, $6\frac{3}{4}$ inches high by $2\frac{3}{8}$ inches in diameter, holds 10 fl. oz., or 300 cubic centimeters. A $\frac{3}{10}$ liter stein, $2\frac{7}{8}$ inches in diameter and $3\frac{3}{4}$ inches deep, holds 10 fl. oz., or 300 cubic centimeters as ordinarily filled.

120 drops water	= 1 teaspoon
60 " thick fluid	= 1 "
60 " " "	= 1 oz.
2 teaspoons	= 1 dessert-spoon
3 "	= 1 tablespoon
16 tablespoons	= 1 cup
1 cup	= ½ pint
1 " water	= ½ lb.
4 tablespoons flour	= 1 oz.
2 tablespoons butter	= 1 "
3 teaspoons soda	= ½ "
4 " baking powder	= ½ "
2 cups granulated sugar	= 1 lb.
2½ " confectioners' sugar	= 1 "
2½ " wheat flour	= 1 "
3½ " whole-wheat flour	= 1 "
2½ cups buckwheat flour	= 1 lb.
5⅓ " coffee	= 1 "
6½ " tea	= 1 "
2 " rice	= 1 "
2 " lard	= 1 "
2 " butter	= 1 "
2 " graham flour	= 1 "
2 " rye flour	= 1 "
2 " corn meal	= 1 "
2 " rolled oats	= 1 "
2 " powdered sugar	= 1 "
2 " brown "	= 1 "
2 " raisins	= 1 "
2 " currants	= 1 "
2 " bread crumbs	= 1 "
9 eggs	= 1 "

FOREIGN WEIGHTS AND MEASURES.

The following table embraces only such weights and measures as are given from time to time in CONSULAR REPORTS and in COMMERCIAL RELATIONS:

Foreign weights and measures, with American equivalents.

Denominations.	Where Used.	American Equivalents.
Almude	Portugal	4.422 gallons.
Ardeb	Egypt	7.6907 bushels.
Are	Metric	0.02471 acre.
Arobe	Paraguay	25 pounds.
Arratel or libra	Portugal	1.011 pounds.
Arroba (dry)	Argentine Republic	25.3175 pounds.
Do	Brazil	32.38 pounds.
Do	Cuba	25.3664 pounds
Do	Portugal	32.38 pounds.
Do	Spain	25.36 pounds.
Do	Venezuela	25.4024 pounds.
Arroba (liquid)	Cuba, Spain, and Venezuela	4.263 gallons.
Arshine	Russia	28 inches.
Arshine (square)	Do	5.44 square feet.
Artel	Morocco	1.12 pounds.
Baril	Argentine Republic and Mexico	20.0787 gallons.
Barrel	Malta (customs)	11.4 gallons.
Do	Spain (raisins)	100 pounds.
Batman or tabriz	Persia	6.49 pounds.
Berkovets	Russia	361.12 pounds.
Bongkal	India	832 grains.
Bouw	Sumatra	7,096.5 square meters.
Bu	Japan	0.1 inch.
Butt (wine)	Spain	140 gallons.
Caffiso	Malta	5.4 gallons.
Candy	India (Bombay)	529 pounds.
Do	India (Madras)	500 pounds.
Cantar	Morocco	113 pounds.
Do	Syria (Damascus)	575 pounds.
Do	Turkey	124.7036 pounds.
Cantaro (cantar)	Malta	175 pounds.
Carga	Mexico and Salvador	300 pounds.
Catty	China	1.333⅓ (1⅓) pounds.
Do.[1]	Japan	1.31 pounds.
Do	Java, Siam, and Malacca	1.35 pounds.
Do	Sumatra	2.12 pounds.
Centaro	Central America	4.2631 gallons.
Centner	Bremen and Brunswick	117.5 pounds.
Do	Darmstadt	110.24 pounds.
Do	Denmark and Norway	110.11 pounds.
Do	Nuremberg	112.43 pounds.
Do	Prussia	113.44 pounds.
Do	Sweden	93.7 pounds.
Do	Vienna	123.5 pounds.
Do	Zollverein	110.24 pounds.

[1] More frequently called "kin." Among merchants in the treaty ports it equals 1.33⅓ pounds avoirdupois.

Denominations.	Where Used.	American Equivalents.
Centner	Double or metric	220.46 pounds.
Chetvert.	Russia	5.7748 bushels.
Chih	China	14 inches.
Coyan	Sarawak	3,098 pounds
Do	Siam (Koyan)	2,667 pounds.
Cuadra	Argentine Republic	4.2 acres.
Do	Paraguay	78.9 yards.
Do	Paraguay (square)	8.077 square feet.
Do	Uruguay	Nearly 2 acres.
Cubic meter	Metric	35.3 cubic feet.
Cwt. (hundredweight)	British	112 pounds.
Dessiatine	Russia	2.6997 acres.
Do	Spain	1.599 bushels.
Drachme	Greece	Half ounce.
Fanega (dry)	Central America	1.5745 bushels.
Do	Chile	2.575 bushels.
Do	Cuba	1.599 bushels.
Do	Mexico	1.54728 bushels.
Do	Morocco	Strike fanega, 70 pounds; full fanega, 118 pounds.
Do	Uruguay (double)	7.776 bushels.
Do	Uruguay (single)	3.888 bushels.
Do	Venezuela	1.599 bushels.
Fanega (liquid)	Spain	16 gallons.
Feddan	Egypt	1.03 acres.
Frail (raisins)	Spain	50 pounds.
Frasco	Argentine Republic	2.5096 quarts.
Do	Mexico	2.5 quarts.
Frasila	Zanzibar	35 pounds.
Fuder	Luxemburg	264 17 gallons.
Funt	Russia	0.9028 pound.
Garnice	Russian Poland	0.88 gallon.
Gram	Metric	15.432 grains.
Hectare	Do	2.471 acres.
Hectoliter.		
Dry	Do	2.838 bushels.
Liquid	Do	26.417 gallons.
Joch	Austria-Hungary	1.422 acres.
Ken	Japan	6 feet.
Kilogram (kilo)	Metric	2.2046 pounds.
Kilometer	Do	0.621376 mile.
Klafter	Russia	216 cubic feet.
Koku	Japan	4.9629 bushels.
Korree	Russia	3.5 bushels
Kwan	Japan	8.28 pounds.
Last	Belgium and Holland	85.134 bushels.
Do	England (dry malt)	82.52 bushels.
Do	Germany	2 metric tons (4,480 pounds).
Do	Prussia	112.29 bushels.
Do	Russian Poland	11⅜ bushels.
Do	Spain (salt)	4,760 pounds.
League (land)	Paraguay	4,633 acres.
Li	China	2,115 feet.
Libra (pound)	Argentine Republic	1.0127 pounds.
Do	Central America	1.043 pounds.
Do	Chile	1.014 pounds.
Do	Cuba	1.0161 pounds.
Do	Mexico	1.01465 pounds.
Do	Peru	1.0143 pounds.
Do	Portugal	1.011 pounds.
Do	Spain	1.0144 pounds.
Do	Uruguay	1.0143 pounds.
Do	Venezuela	1.0161 pounds.
Liter	Metric	1.0567 quarts.
Livre (pound)	Greece	1.1 pounds.
Do	Guiana	1.0791 pounds.
Load	England (timber)	Square, 50 cubic feet; unhewn, 40 cubic feet; inch planks, 600 superficial feet.
Manzana	Costa Rica	1⅝ acres.
Do	Nicaragua and Salvador	1.727 acres.

Denominations.	Where Used.	American Equivalents.
Marc	Bolivia	0.507 pound.
Maund	India	82⅔ pounds.
Meter	Metric	39.37 inches.
Mil	Denmark	4.68 miles.
Do	Denmark (geographical)	4.61 miles.
Milla	Nicaragua and Honduras	1.1493 miles.
Morgen	Prussia	0.63 acre.
Oke	Egypt	2.7225 pounds.
Do	Greece	2.84 pounds.
Do	Hungary	3.0817 pounds.
Do	Turkey	2.82838 pounds.
Do	Hungary and Wallachia	2.5 pints.
Pic	Egypt	21¼ inches.
Picul	Borneo and Celebes	135.64 pounds.
Do	China, Japan, and Sumatra	133⅓ pounds.
Do	Java	135.1 pounds.
Do	Philippine Islands	137.9 pounds.
Pie	Argentine Republic	0.9478 foot.
Do	Spain	0.91407 foot.
Pik	Turkey	27.9 inches.
Pood	Russia	36.112 pounds.
Pund (pound)	Denmark and Sweden	1.102 pounds.
Quarter	Great Britain	8.252 bushels.
Do	London (coal)	36 bushels.
Quintal	Argentine Republic	101.42 pounds.
Do	Brazil	130.06 pounds.
Do	Castile,[1] Chile, Mexico, and Peru	101.41 pounds.
Do	Greece	123.2 pounds.
Do	Newfoundland (fish)	112 pounds.
Do	Paraguay	100 pounds.
Do	Syria	125 pounds.
Do	Metric	220.46 pounds
Rottle	Palestine	6 pounds.
Do	Syria	5⅝ pounds.
Sagene	Russia	7 feet.
Salm	Malta	490 pounds.
Se	Japan	0.02451 acre.
Seer	India	1 pound 13 ounces.
Shaku	Japan	11.9305 inches.
Sho	Do	1.6 quarts.
Standard (St. Petersburg)	Lumber measure	165 cubic feet.
Stone	British	14 pounds.
Suerte	Uruguay	2,700 cuadras (see cuadra).
Sun	Japan	1.193 inches.
Tael	Cochin China	590.75 grains (troy).
Tan	Japan	0.25 acre.
To	Do	2 pecks.
Ton	Space measure	40 cubic feet.
Tonde (cereals)	Denmark	3.94783 bushels.
Tondeland	Do	1.36 acres.
Tsubo	Japan	6 feet square.
Tsun	China	1.41 inches.
Tunna	Sweden	4.5 bushels.
Tunnland	Sweden	1.22 acres.
Vara	Argentine Republic	34.1208 inches.
Do	Central America	32.87 inches.
Do	Chile and Peru	33.367 inches.
Do	Cuba	33.384 inches.
Do	Curacao	33.375 inches.
Do	Mexico	33 inches.
Do	Paraguay	34 inches.
Do	Spain	0.914117 yard.
Do	Venezuela	33.384 inches.
Vedro	Russia	2.707 gallons.
Vergees	Isle of Jersey	71.1 square rods.
Verst	Russia	0.663 mile.
Vlocka	Russian Poland	41.98 acres.

[1] Although the metric weights are used officially in Spain, the Castile quintal is employed in commerce in the Peninsula and colonies, save in Catalonia; the Catalan quintal equals 91.71 pounds.

A *meter* is one ten-millionth of the distance from the equator to the North Pole.

The metric system, formed on the meter as the unit of length, has four other leading units, all connected with and dependent upon this. The *are*, the unit of surface, is the square of ten meters. The *liter*, the unit of capacity, is the cube of a tenth part of the meter. The *stere*, the unit of solidity, has the capacity of a cubic meter. The *gram*, the unit of weight, is the weight of that quantity of distilled water at its maximum density which fills the cube of a hundredth part of the meter. Each unit has its decimal multiple and submultiple, that is, weights and measures ten times larger or ten times smaller than the principal unit. The prefixes denoting the multiples are derived from the Greek, and are *deca*, ten; *hecto*, hundred; *kilo*, thousand; and *myria*, ten thousand. Those denoting sub-multiples are taken from the Latin, and are *deci*, ten; *centi*, hundred; *milli*, thousand.

Relative Value.	Length.	Surface.	Capacity.	Solidity.	Weight.
10,000.	Myriameter				
1,000.	Kilometer		Kiloliter		Kilogram
100.	Hectometer	Hectare	Hectoliter		Hectogram
10.	Decameter		Decaliter	Dekastere	Decagram
Unit.	Meter	Are	Liter	Stere	Gram
0.1.	Decimeter	Deciare	Deciliter	Decistere	Decigram
0.01.	Centimeter	Centiare	Centiliter		Centigram
0.001.	Millimeter		Milliliter		Milligram

APPROXIMATE EQUIVALENTS OF THE FRENCH (METRIC) AND ENGLISH MEASURES.

1 yard	$\frac{11}{12}$ meter.
11 meters	12 yards.
To convert meters into yards	Add $\frac{1}{11}$th.
1 meter = 1.1 yd.; 3.3 ft.	3 ft. $3\frac{3}{8}$ inches ($\frac{1}{512}$th less). 40 inches (1.6 per cent less).
1 meter, by the Standards Commission	= 39.38203 inches.
1 meter, by the Act of 1878	= 39.37079 inches.
1 foot	3 decimeters (more exactly 3.048).
1 inch	25 millimeters (more exactly 25.4).
1 mile	1.6 or $1\frac{3}{5}$ kilometers (more exactly 1.60931).
1 kilometer	$\frac{5}{8}$ of a mile.
1 chain (22 yards)	20 meters (more exactly 20.1165).
5 furlongs (1,100 yards)	1 kilometer (more exactly 1.0058).
1 square yard	$\frac{5}{6}$ square meter (more exactly .8361).
1 square meter	$10\frac{3}{4}$ square feet. $1\frac{1}{5}$ square yards.
1 square inch	$6\frac{1}{2}$ square centimeters (more exactly 6.45).
1 square mile (640 acres)	260 hectares (0.4 per cent less).
1 acre (4840 square yards)	4000 square meters (1.2 per cent more).
1 cubic yard	$\frac{3}{4}$ cubic meter (2 per cent more).
1 cubic meter	$1\frac{1}{3}$ cubic yards ($1\frac{2}{3}$ per cent less).
1 cubic meter	$35\frac{1}{3}$ cubic feet (.05 per cent less).
1 cubic meter of water	1 long ton nearly.
1 kilogram	2.2 pounds fully.
1,000 kilograms 1 metric ton	1 long ton nearly.
1 long hundredweight	51 kilograms nearly.
1 United States hundredweight	$45\frac{1}{2}$ kilograms nearly.

METRIC MEASURES.

Measures.		Metric to Customary.	Customary to Metric.
Lengths		1 Millimeter = 0.03937 inch	1 Inch = 25.4001 millimeters
		1 Centimeter = 0.3937 "	1 " = 2.54001 centimeters
		1 Meter = 39.37 "	1 " = 0.0254 meter
		1 " = 3.28083 feet	1 Foot = 0.304801 "
		1 " = 1.093611 yards	1 Yard = 0.914402 "
		1 Kilometer = 0.62137 mile	1 Mile = 1.60935 kilometers
Areas		1 Square Millimeter = 0.00155 square inch	1 Square Inch = 645.16 square millimeters
		1 " Centimeter = 0.1550 " "	1 " " = 6.452 " centimeters
		1 " Meter = 10.764 " feet	1 " Foot = 0.0929 " meter
		1 " " = 1.1960 " yards	1 " Yard = 0.8361 " "
		1 " Kilometer = 0.3861 " mile	1 " Mile = 2.5900 " kilometers
		1 Hectare = 2.471 acres	1 Acre = 0.4047 hectares
Volumes		1 Cubic Millimeter = 0.000061 cubic inch	1 Cubic Inch = 16,387.2 cubic millimeters
		1 " Centimeter = 0.0610 " "	1 " " = 16.3872 " centimeters
		1 " Meter = 35.314 " feet	1 " Foot = 0.02832 " meter
		1 " " = 1.3079 " yard	1 " Yard = 0.7645 " "
Capacity	*Liquid*	1 Liter = 1.05668 quarts	1 Quart = 0.94636 liter
		1 " = 0.26417 gallon	1 Gallon = 3.78543 "
	Dry	1 Liter = 0.9081 quart	1 Quart = 1.1012 liters
		1 " = 0.11351 peck	1 Peck = 8.80982 "
		1 Decaliter = 1.1351 "	1 " = 0.8810 decaliter
		1 Hectoliter = 2.83774 bushels	1 Bushel = 0.35239 hectoliter
Masses	*Avoirdupois*	1 Gram = 15.4324 grains	1 Grain = 0.06480 gram
		1 " = 0.03527 ounce	1 Ounce = 28.3495 "
		1 Kilogram = 2.20462 pounds	1 Pound = 0.45359 kilogram
	Troy	1 Gram = 0.03215 ounce	1 Ounce = 31.10348 grams
		1 Kilogram = 2.67923 pounds	1 Pound = 0.37324 kilogram
	Apothecaries'	1 Gram = 0.2705 dram	1 Dram = 3.6967 grams
		1 " = 0.8115 scruple	1 Scruple = 1.2322 "

1 kilogram per linear meter	.672 pound per linear foot. 2.016 pounds per yard.
1,000 kilograms (1 ton) per meter	.300 long ton per foot; 1/3 short ton per foot.
1 kilogram per kilometer	3.548 pounds per mile.
1,000 kilograms (1 ton) per kilometer	1.584 long tons per mile; 1.774 short tons per mile.
1 kilogram per square millimeter	1422.32 pounds per square inch; .635 long ton per square inch; .711 short ton per sq. in.
1 kilogram per square centimeter	14.2232 pounds per square inch.
1 kilogram per square decimeter	20.481 pounds per square foot.
1 kilogram per square meter	1.843 pounds per square yard.
1,000 kilograms (1 ton) per square meter	.8229 long ton, .922 short ton, per square yard.
1 kilogram per ton	2.240 pounds per long ton; 2 pounds per short ton.
1 kilogram per ton per kilometer	3.6042 pounds per long ton per mile.
1 liter of water at 4° C. per ton per kilometer	.4325 U. S. gal. at 62° F. per long ton per mile.
1 gram per square millimeter	1.422 pounds per square inch.
1 gram per square centimeter	.01422 pound per square inch.
1 kilogram per cubic meter	.1686 pound per cubic yard. .0624 pound per cubic foot.
1,000 kilograms (1 ton) per cubic meter	.934 long ton per cubic meter. .752 ton per cubic yard.
1 cubic meter per kilogram	16.019 cubic feet per pound.
1 cubic meter per ton	1.329 cubic yards per long ton. 35.882 cubic feet per long ton.
1 cubic meter per kilometer	2.105 cubic yards per mile.
1 cubic meter per linear meter	1.196 cubic yards per linear yard.
1 cubic meter per square meter	3.281 cubic feet per square foot.
1 cubic meter per hectare	.405 cubic meter per acre. .529 cubic yard per acre.
1 kilogrammeter	7.233 foot-pounds.
1 kilogrammeter	=0.00323 foot-ton (long)=.00362 foot-ton (short).
1 ton-meter	3 foot-tons (long); 3.36 (short).
1 cheval vapeur, or cheval (75k×m per second)	.9863 horse-power.
1 kilogram per cheval	2.235 pounds per horse-power.
1 square meter per cheval	10.913 square feet per horse-power.
1 cubic meter per cheval	35.806 cubic feet per horse-power.
1 calorie, or French unit of heat	3.968 British heat-units.
French mechanical equivalent of heat (423.55k×m)	3063.5 foot-pounds.
1 calorie per square meter	.369 heat-unit per square foot.
1 calorie per kilogram	1.800 heat-units per pound.

ENGLISH AND FRENCH.

1 pound per linear foot	1.488 kilograms per linear meter.
1 pound per yard	.496 kilogram per meter.
1 long ton per foot	33.32 kilograms (3 1/3 tons approx.) per meter.
1 long ton per yard	1111 kilograms (1 1/10 tons approx.) per meter.
1 pound per mile	.2818 kilogram per kilometer.
1 long ton per mile	.6313 ton per kilometer.
1 pound per long ton	.4464 kilogram per ton.
1 pound per long ton per mile	.2774 kilogram per ton per kilometer.
1 pound per square inch	.0703077 kilogram per square centimeter. .7031 gram per square millimeter. 5.170 centimeters of mercury at 0° C.
1 atmosphere (14.7 pounds per square inch)	1.0335 kilograms per square centimeter.
1,000 pounds per square inch	.703077 kilogram per square millimeter.
2,000 pounds per square inch	1.406154 kilograms per square millimeter.
1 long ton per square inch	1.575 kilograms per square millimeter.
1 pound per square foot	4.883 kilograms per square meter
1,000 pounds per square foot	4882.517 kilograms per square meter.
1 ton per square foot	10.936 tons per square meter.
1,000 pounds per square yard	542.500 kilograms per square meter.
1 ton per square yard	1.215 tons per square meter.
1 pound per cubic yard	.5933 kilogram per cubic meter.
1 pound per cubic foot	16.020 kilograms per cubic meter.
1 ton per cubic yard	1.329 tons per cubic meter.
1 cubic yard per pound	1.6855 cubic meters per kilogram.
1 cubic yard per ton	.7525 cubic meter per ton.
1 cubic yard per mile	.4750 cubic meter per kilometer.
1 cubic yard per linear yard	.836 cubic meter per linear meter.
1 cubic foot per square foot	.3048 cubic meter per square meter.
1 cubic meter per acre	2.471 cubic meters per hectare.
1 cubic yard per acre	1.889 cubic meters per hectare.
1 foot-pound	.1382 kilogrammeter.

1 foot-ton (long)	.3097 ton-meter.
1 horse-power	1.0139 cheval.
1 pound per horse-power	.447 kilogram per cheval.
1 square foot per horse-power	.0916 square meter per cheval.
1 cubic foot per horse-power	.0279 cubic meter per cheval.
1 British unit of heat, or heat-unit	.252 calorie.
British mechanical equivalent of one heat-unit (772 foot-pounds)	106.7 kilogrammeters.
1 British heat-unit per square foot	2.713 calories per square meter.
1 British heat-unit per pound	$\frac{5}{9}$ calorie per kilogram.

—D. K. Clark, Mechanical Engineer's Pocket Book.

TO REDUCE PARTS BY VOLUME, OR MEASURE TO PARTS BY WEIGHT.—Multiply the parts by volume, or measure, by the specific gravity of the different substances: the result will be parts by weight.

MENSURATION.

SURFACES.

PARALLELOGRAM.—Area equals base multiplied by height.

TRIANGLE.—Base and height given. Multiply base by height and divide by two.

When three sides are given. From the half sum of the three sides subtract each side separately; multiply the half sum and the three remainders together. The area is the square root of the product thus obtained.

TRAPEZIUM (a figure with two sides parallel and two sides not parallel).—To find the area multiply the sum of the two parallel sides by the distance between them and divide by two.

SQUARE OR RHOMBUS (an oblique parallelogram with four equal sides).—Area equals half the product of the diagonals.

IRREGULAR POLYGON.—The area may be found by dividing it into a series of triangles and trapeziums, and finding the sum of the areas thus obtained.

REGULAR POLYGON.—Area equals number of sides multiplied by length of one side and by the radius of the inscribed circle divided by two.

CIRCLE.—Circumference equals diameter multiplied by 3.1416, or approximately by $3\frac{1}{7}$. Area equals diameter squared multiplied by .7854.

SECTOR OF CIRCLE.—Multiply the length of the arc by the radius and divide by two.

SEGMENT OF CIRCLE.—Find the area of the sector having the same arc. Also find area of triangle formed by the radial sides and the chord. The area equals the sum or difference of these according as the segment is greater or less than a semicircle.

ANNULUS.—Multiply the sum of the diameters by their difference and by .7854.

SQUARE EQUAL TO A CIRCLE.—Side of square equals diameter multiplied by .8862.

INSCRIBED SQUARE.—Side of square equals diameter multiplied by .7071.

ELLIPSE.—Area equals the product of the two axes by .7854.

SOLIDS.

CUBE.—Surface equals length of one edge squared and multiplied by six. Contents equals length of one edge cubed.

CYLINDERS AND PRISMS.—Surface equals perimeter of one end multiplied by height plus twice the area of one end. Contents equals area of base multiplied by height. This last also applies to oblique cylinders and prisms.

CONE OR PYRAMID.—Surface equals circumference of base multiplied by slant height divided by two, plus the area of the base. Contents equals area of base multiplied by one-third perpendicular height. This last applies whether the cones and pyramids be right or oblique.

FRUSTUM OF CONE OR PYRAMID.—Contents: To the sum of the area of the two ends add the square root of their product and multiply the quantity thus obtained by one-third the perpendicular height.

SPHERE.—Area equals square of diameter multiplied by 3.1416 or $3\frac{1}{7}$; *i.e.*, it is equal to four times the area of one of its great circles, or to the convex surface of its circumscribing cylinder. Surfaces of spheres vary as the squares of their diameters. Contents equal the cube of the diameter multiplied by .5236, *i.e.*, equals area of surface multiplied by diameter and divided by six. Contents of spheres vary as the cubes of the diameter.

SEGMENT OF SPHERE.—Contents: From three times the diameter of the sphere subtract twice the height of the segment, multiply the difference by the square of the height and by .5236; or, another rule: Add the square of the height to three times the square of the radius of the base and multiply the sum by the height and by .5236.

ZONE OF SPHERE.—To the sum of the squares of the radii of the two ends add one-third the square of the height, multiply the sum by the height and by 1.5708.

CONE, SPHERE, AND CYLINDER.—The contents of a cone, sphere, and cylinder of same diameter and height are in the ratio of 1 to 2 to 3.—*Practical Engineer's Electrical Pocket Book and Diary.*

CIRCULAR MEASURE.

Diameter of a Circle × 3.1416 gives Circumference.

Diameter Squared × .7854 gives Area of Circle.

Diameter Squared × 3.1416 gives Surface of Sphere.

Diameter Cubed × .5236 gives Solidity of Sphere.

One Degree of Circumference × 57.3 gives Radius.

Diameter of Cylinder × 3.1416, and product by its length, gives the Surface.

Diameter Squared × .7854, and product by the length, gives Solid Contents.

A Circular Acre is 225.504 feet, a Circular Rood 117.752 feet, in diameter. The Circumference of the globe is about 24,855 miles, and the Diameter about 7,900 miles.—*Whittaker's Almanac.*

ANGULAR MEASURE.

There is perfect unanimity as to the standard angle (i.e., the right angle) and practical unanimity as to its subdivision, for the subdivision into grades, etc., once favored by the French, is now abandoned.

1 minute of angle or arc	= 60 seconds.
1 degree " " " "	= 60 minutes.
90 degrees " " " "	= 1 right angle or ¼ of circumference.
Radian " " " "	= arc same length as radius.
" " " " "	= 57.295779513082°.
Length of arc of 1°	= 0.017453292520.
Length of arc of 1′	= 0.000290888209.
" " " " 1″	= 0.015707963268.

TIME.

The unit of time measurement is the same among all nations. Practically it is $\frac{1}{86400}$ of the mean solar day, but really it is a perfectly arbitrary unit, as the length of the mean solar day is not constant for any two periods of time. There is no constant natural unit of time.

1 minute	= 60 seconds.
1 hour	= 60 minutes, 3600 seconds.
1 day	= 24 hours, 1440 minutes, 86,400 seconds.
1 sidereal day	= 86164.1 seconds.
1 sidereal month	= 27.321661 mean solar days (average).
1 lunar month	= 29.530589 mean solar days (average).
1 anomalistic month	= 27.544600 mean solar days (average).
1 tropical month	= 27.321582 mean solar days (average).
1 nodical month	= 27.212222 mean solar days (average).
Mean solar year	= 365 d. 5 h. 48 m. 46.045 s. with annual variation of 0.00539.

The change in the length of the mean sidereal day, i.e., of the time of the earth's rotation upon its axis, amounts to 0.01252 s. in 2400 mean solar years.

—*Physical Tables.*

TABLE OF DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH.

$\frac{1}{64}$ = ·015625	$\frac{11}{32}$ = ·34375	$\frac{43}{64}$ = ·671875
$\frac{1}{32}$ = ·03125	$\frac{23}{64}$ = ·359375	$\frac{11}{16}$ = ·6875
$\frac{3}{64}$ = ·046875	$\frac{3}{8}$ = ·375	$\frac{45}{64}$ = ·703125
$\frac{1}{16}$ = ·0625	$\frac{25}{64}$ = ·390625	$\frac{23}{32}$ = ·71875
$\frac{5}{64}$ = ·078125	$\frac{13}{32}$ = ·40625	$\frac{47}{64}$ = ·734375
$\frac{3}{32}$ = ·09375	$\frac{27}{64}$ = ·421875	$\frac{3}{4}$ = ·75
$\frac{7}{64}$ = ·109375	$\frac{7}{16}$ = ·4375	$\frac{49}{64}$ = ·765625
$\frac{1}{8}$ = ·125	$\frac{29}{64}$ = ·453125	$\frac{25}{32}$ = ·78125
$\frac{9}{64}$ = ·140625	$\frac{15}{32}$ = ·46875	$\frac{51}{64}$ = ·796875
$\frac{5}{32}$ = ·15625	$\frac{31}{64}$ = ·484375	$\frac{13}{16}$ = ·8125
$\frac{11}{64}$ = ·171875	$\frac{1}{2}$ = ·50	$\frac{53}{64}$ = ·828125
$\frac{3}{16}$ = ·1875	$\frac{33}{64}$ = ·515625	$\frac{27}{32}$ = ·84375
$\frac{13}{64}$ = ·203125	$\frac{17}{32}$ = ·53125	$\frac{55}{64}$ = ·859375
$\frac{7}{32}$ = ·21875	$\frac{35}{64}$ = ·546875	$\frac{7}{8}$ = ·875
$\frac{15}{64}$ = ·234375	$\frac{9}{16}$ = ·5625	$\frac{57}{64}$ = ·890625
$\frac{1}{4}$ = ·25	$\frac{37}{64}$ = ·578125	$\frac{29}{32}$ = ·90625
$\frac{17}{64}$ = ·265625	$\frac{19}{32}$ = ·59375	$\frac{59}{64}$ = ·921875
$\frac{9}{32}$ = ·28125	$\frac{39}{64}$ = ·609475	$\frac{15}{16}$ = ·9375
$\frac{19}{64}$ = ·296875	$\frac{5}{8}$ = ·625	$\frac{61}{64}$ = ·953125
$\frac{5}{16}$ = ·3125	$\frac{41}{64}$ = ·640625	$\frac{31}{32}$ = ·96875
$\frac{21}{64}$ = ·328125	$\frac{21}{32}$ = ·65625	$\frac{63}{64}$ = ·984375

WEIGHTS AND MEASURES OF THE BIBLE.

WEIGHTS.

	Avoirdupois. Lbs.	Oz.	Drs.		Troy. Lbs.	Oz.	Dwt.	Gr.
A gerah	0	0	0.439	=	0	0	0	12
10 gerahs = 1 bekah	0	0	4.39	=	0	0	5	0
2 bekahs = 1 shekel	0	0	8.78	=	0	0	10	0
60 shekels = 1 maneh	2	0	14.628	=	2	6	0	0
50 manehs = 1 talent	102	13	11.428	=	125	0	0	0

MEASURES.

Long Measure.	Ft.	In.
A digit, or finger (Jer. lii. 21)	0	0.912
4 digits = 1 palm (Exod. xxv. 25)	0	3.648
3 palms = 1 span (Exod. xxviii. 16)	0	10.944
2 spans = 1 cubit (Gen. vi. 15)	1	9.888
4 cubits = 1 fathom (Acts xxvii. 28)	7	3.552
1.5 fathoms = 1 reed (Ezek. xl. 3, 5)	10	11.328
13.3 reeds = 1 line (Ezek. xl. 3)	145	11.04

Land Measure.	Eng. miles.	Paces.	Ft.
A cubit	0	0	1.824
400 cubits = 1 furlong (Luke xxiv. 13)	0	145	4.6
5 furlongs = 1 sabbath day's journey (John xi. 18; Acts i. 12)	0	727	3.0
10 furlongs = 1 mile (Matt. v. 41)	1	399	1.0
24 miles = 1 day's journey	33	76	4.0

Liquid Measure.	Gals.	Pts.
A caph	0	0.625
1.3 caphs = 1 log (Lev. xiv. 10)	0	0.833
4 logs = 1 cab	0	3.333
3 cabs = 1 hin (Exod. xxx. 24)	1	2
2 hins = 1 seah	2	4
3 seahs = 1 bath, or ephah (1 Kings vii. 26; John ii. 6)	7	4.5
10 ephahs = 1 kor, or homer (Isa. v. 10; Ezek. xiv. 14)	75	5.25

Dry Measure.	Pecks.	Gals.	Pts.
A gachal	0	0	0.1416
20 gachals = 1 cab (2 Kings vi. 25; Rev. vi. 6)	0	0	2.8333
1.8 cabs = 1 omer (Exod. xvi. 36)	0	0	5.1
3.3 omers = 1 seah (Matt. xiii. 33)	1	0	1
3 seahs = 1 ephah (Ezek. xlv. 11)	3	0	3
5 ephahs = 1 letech (Hosea iii. 2)	16	0	0
2 letechs = 1 kor, or homer (Num. xi. 32; Hos. iii. 2)	32	0	0

N.B.—The above Table will explain many texts in the Bible. Take, for instance, Isa. v. 10: "Yea, ten acres of vineyard shall yield one bath, and the seed of an homer shall yield an ephah." This curse upon the covetous man was, that 10 acres of vines should produce only 7 gallons of wine, i.e., one acre should yield less that 3 quarts; and that 32 pecks of seed should only bring a crop of 3 pecks, or, in other words, that the harvest reaped should produce but one-tenth of the seed sown.

TIME.

The *Natural* Day was from sun-rise to sun-set.
The *Natural* Night was from sun-set to sun-rise.
The *Civil* Day was from sun-set one evening to sun-set the next; for, "the Evening and the Morning were the first day."

Night (*Ancient*).

First Watch (Lam. ii. 19) till midnight.
Middle Watch (Judg. vii. 19) till 3 a.m.
Morning Watch (Exod. xiv. 24) till 6 a.m.

Night (*New Testament*).

First Watch, *evening* = 6 to 9 p.m.
Second Watch, *midnight* = 9 to 12 p.m.
Third Watch, *cock-crow* = 12 to 3 a.m.
Fourth Watch, *morning* = 3 to 6 a.m.

Day (*Ancient*).

Morning till about 10 a.m.
Heat of day till about 2 p.m.
Cool of day till about 6 p.m.

Day (*New Testament*).

Third hour = 6 to 9 a.m.
Sixth hour = 9 to 12 midday.
Ninth hour = 12 to 3 p m.
Twelfth hour = 3 to 6 p.m.

JEWISH MONEY.

With its value in English and American money; the American dollar being taken as equal to 4s. 2d.

Jewish.		English.				American.	
		£	*s.*	*d.*		*Dols.*	*Cents.*
A gerah (Exod. xxx. 13)	=	0	0	1.36	=	0	2.73
10 gerahs = 1 bekah (Exod. xxxviii. 26)	=	0	1	1.68	=	0	27.37
2 bekahs = 1 shekel (Exod. xxx. 13; Isa. vii. 23)	=	0	2	3.37	=	0	54.74
50 shekels = 1 maneh	=	5	14	0.75	=	27	37.50
60 manehs = 1 kikkar (talent)	=	342	3	9	=	1,642	50
A *gold* shekel	=	1	16	6	=	8	76
A kikkar of gold	=	5,475	0	0	=	26,280	0

N.B.—A *shekel* would probably purchase nearly ten times as much as the same nominal amount will now. Remember that one *Roman* penny (8½*d.*) was a good day's wages for a laborer.

The Hebrew *maneh*, according to 1 Kings x. 17, compared with 2 Chron. ix. 16, contained 100 shekels; though according to one interpretation of Ezek. xlv. 12, it contained 60, but more probably 50. The passage reads thus:—"Twenty shekels, five and twenty shekels. fifteen shekels shall be your maneh." This is variously interpreted, (1) 20+25+15 =60. (2) 20, 25, 15 are different coins in gold, silver, and copper, bearing the same name. It is well to remark the meaning of these names: Shekel = simply *weight:* Bekah = *split*, i.e., the shekel divided into two: Gerah = a *grain*, as in our weights, a grain and a *barley-corn*, the original standard weight: Maneh = *appointed*, equivalent to *sterling*, a specific sum: Kikkar = a *round* mass of metal, i.e., a weight or coin. Hebrew names of weights and coins are not found in the New Testament: *mna* in Luke xix. 13 is Greek, though possibly identical with the Hebrew *maneh*.

ROMAN MONEY.

Roman.	English.		American.
	d.		*Cents.*
A "farthing," *quadrans* (Matt. v. 26) = nearly	0.125	=	0.25
A "farthing," *as* = 4 *quadrantes* (Matt. x. 29) = nearly	0.5	=	1
A "penny," *denarius* = 16 *asses* (Matt. xxii. 19) = nearly	8.50	=	17

[The Roman sestertius = 2½ asses, is not named in the Bible.]

N.B.—Here we learn that—

Naaman's offering to Elisha of 6,000 pieces (shekels) of gold amounted to more than £10,000 = 48,000 *dollars*.

The Debtor (Matt. xviii. 24) who had been forgiven 10,000 talents, i.e., £3,000,000 = 14,400,000 *dollars*, refused to forgive his fellow-servant 100 pence, i.e., £3 10*s.* 10*d* = 17 *dollars*.

Judas sold our Lord for 30 pieces of silver, i.e., £3 10*s.* 8*d.* = 16 *dollars* 96 *cents*, the legal value of a slave, if he were killed by a beast.

Joseph was sold by his brethren for 20 pieces, i.e. £2 7*s.* = 11 *dollars* 28 *cents*.

—*Oxford University Bible.*

WATCH.—For purposes of discipline, and to divide the work fairly, the crew is mustered in two divisions: the Starboard (right side, looking forward) and the Port (left). The day commences at noon, and is thus divided:—

Afternoon *Watch*	....	noon to 4 p.m.
First Dog "	....	4 p.m. to 6 p.m.
Second Dog "	....	6 p.m. to 8 p.m.
First "	....	8 p.m. to midnight.
Middle "	....	12 p.m. to 4 a.m.
Morning "	....	4 a.m. to 8 a.m.
Forenoon "	....	8 a.m. to noon.

This makes seven WATCHES, which enables the crew to keep them alternately, as the *Watch* which is on duty in the forenoon one day has the afternoon next day, and the men who have only four hours' rest one night have eight hours the next. This is the reason for having *Dog Watches*, which are made by dividing the hours between 4 p.m. and 8 p.m. into two *Watches*.

TIME.—Time is kept by means of "Bells," although there is but one bell on the ship, and to strike the clapper properly against the bell requires some skill.

First, two strokes of the clapper at the interval of a second, then an interval of two seconds; then two more strokes with a second's interval apart, then a rest of two seconds, thus:—

BELL, ONE SECOND; B., TWO SECS.; B. s.; B. ss; B. s.; B. ss.; B.

1 Bell is struck at 12.30, and again at 4.30, 6.30, 8.30 p.m.; 12.30, 4.30, and 8.30 a.m.

2 Bells at 1 (struck with an interval of a second between each—B. s, B.), the same again at 5, 7, and 9 p.m.; 1, 5, and 9 a.m.

3 Bells at 1.30 (B. s, B. ss, B.), 5.30, 7.30, and 9.30 p.m.; 1.30, 5.30, and 9.30 a.m.

4 Bells at 2 (B. s, B. ss, B. s, B.), 6 and 10 p.m.; 2, 6, and 10 a.m.

5 Bells at 2.30 (B. s, B ss, B. s, B. ss, B.) and 10.30 p.m.; 2.30, 6.30, and 10.30 a.m.

6 Bells at 3 (B. s, B. ss, B. s, B. ss, B. s, B.) and 11 p.m.; 3, 7, and 11 a.m.

7 Bells at 3.30 (B. s, B. ss, B. s, B. ss, B. s, B. ss, B.) and 11.30 p.m.; 3.30, 7.30, and 11.30 a.m.

8 Bells (B. s, B. ss, B. s, B. ss, B. s, B. ss, B. s, B.) every 4 hours, at noon, at 4 p.m., 8 p.m., midnight, 4 a.m., and 8 a.m.

—*Whittaker's Almanac.*

STONES: SPECIFIC GRAVITY, WEIGHT AND VOLUME.

STONES.	Specific. Gravity.	Weight of one Cubic Foot.	Cubic Feet per Ton.
	Water = 1.	Pounds.	Cubic Ft.
Alabaster, calcareous	2.76	172.1	13.0
" gypseous	2.31	144.0	15.6
Barytes	4.45	277.5	8.07
Basalt	2.45–3.00	152.8–187.1	14.7–12.0
Chalk, air-dried	2.78	155	14.5
Diamond	3.50	....	....
Flint	2.59	164	13.7
Felspar	2.60	162.1	13.8
Gneiss	2.69	168	13.3
Granite	2.50–2.74	156–171	14.4–13.1
Graphite	2.20	137.2	16.3
Jasper	2.72	169.7	13.2
Limestone	1.86–2.53	116–158	19.3–14.2
Marble:			
African	2.80	174.6	12.8
British	2.71	169.0	13.3
Carrara	2.72	169.6	13.2
Egyptian green	2.67	166.5	13.5
Florentine	2.52	157.1	14.3
French	2.65	165.2	13.6
Mica	2.93	183	12.2
Oolitic stones	1.89–2.60	118–162	19.0–13.8
Ores:			
Spicular or red iron ore	5.21	327.4	6.84
Magnetic iron ore	5.09	317.6	7.05
Brown iron ore	3.92	244.6	9.16
Spathic iron ore	3.83	238.8	9.38
Quartz	2.61–2.71	162.8–169	13.8–13.3
Sandstone	2.04–2.70	127–168	17.6–13.3
Serpentine	2.81	175.2	12.8
Slate	2.60–2.85	162.1–177.7	13.8–12.6
Talc, steatite	2.70	168.4	13.3

SUBSTANCES.	Specific Gravity.	Weight of One Cubic Foot.	Cubic Feet per Ton
	Water = 1.	Pounds.	Cubic Ft.
Alum	1.72	107.2	20.9
Ballast (brick rubbish and gravel)	1.80	112	20.0
Brick	1.90–2.40	124.7–135.3	18.1–16.0
Brickwork	1.76–1.84	110	20.4–18
Camphor	.99	61.7	36.3
Clay	1.92	119.7	18.7
Coal:			
Anthracite	1.37–1.59	85.4–99.1	26.2–22.6
Bituminous	1.20–1.31	74.8–81.7	30–28.1
Earth, argillaceous:	....	93–137	16–24
Dry, loose	1.15–1.29	72–80	31.1–28
Dry, shaken	1.32–1.48	82–92	27.3–24.3
Moist, loose	1.06–1.22	66–76	34.0–29.5
Packed	1.44–1.60	90–100	24.8–22.4
Glass:			
Flint	2.90	187.0	12.0
Green	2.70	168.4	13.3
Plate	2.70	168.4	13.3
Thick flooring	2.53	158.0	14.2
Crown	2.50	155.9	14.4
Gunpowder, heaped	1.75–1.84	109.1–114.7	20.5–19.5
Ice, melting	.922	57.5	39
Marl	1.60–1.90	99.8–118.5	22.4–18.9
Masonry:			
Ashlar granite	2.37	147.5	15.2
" Limestone, hard	2.70	168.5	11.4
" " semi-hard	2.42	151.9	14.8
" " soft	2.34	145.6	15.4
" Sandstone	2.61	162.5	13.2
Rubble, dry	2.21	138	16.2
" mortar	2.47	154	14.6
Mortar, hardened	1.65	103	21.7
Mud:			
Dry, close	1.28–1.93	80–110	28.0–20.4
Wet, moderately pressed	1.93–2.09	110–130	20.4–17.2
Wet, fluid	1.67–1.92	104–120	21.5–18.7
Phosphorus	1.77	110.4	20.3
Plaster	1.87–2.47	98	22.9
Portland cement	1.25–1.51	78–94	28.7–23.8
Potash	2.10	131	17.1
Sand	1.44–1.87	90–117	24.9–19.1
" saturated with water	1.89–2.07	118–129	19–17.4
Salt, common	1.92	119.7	18.7
" rock	2.10–2.26	131–140.7	17.1–15.9
Sulphur	2.00	124.7	18.0
Tiles	2.00	124.7	18.0

Fuels.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Ton, Heaped.
		Solid.	Heaped.	
Coals.	Water = 1.	Lbs.	Lbs.	Cub. Ft.
Anthracite, American	1.30–1.84	93.5	54.0	....
Bituminous coal, American	1.27	84.0	50.0	....
Coke.				
Coke, generally	....	40–50	30.0	70–80
American	....	....	32.1	69.8
Graphite	2.33	145.3	....	....
Lignite and Asphalt.				
Perfect lignite	1.29	....	....	....
Imperfect lignite	1.15	....	....	....
Bituminous lignite	1.18	....	....	....
Asphalt	1.06	....	....	....
Wood Charcoal. *As made, heaped.*	Heaped.			
Oak and beech	.24–.25	....	15–15.6	....
Birch	.22–.23	....	13.7–14.3	....
Pine	.20–.21	....	12.5–13.1	....
Average	.225	....	14	....
Gunpowder, loose	.90	....	....	....
" shaken	1.00	....	....	....
" solid	1.55–1.80	....	....	....

WOODS: SPECIFIC GRAVITY AND WEIGHT.

Wood.	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	Pounds.
Ash	.84	52.4
" with 20 per cent. moisture	.70	43.7
Apple tree	.79	45.5
Bamboo	.31–.40	19.5–24.9
Beech	.75–.85	46.8–50.3
" with 20 per cent. moisture	.82	51.1
" cut one year	.66	41.2
Birch	.72–.74	44.9–46.1
Boxwood	1.04	64.8
Cedar of Lebanon	.49–.57	30.6–35.5
Cork	.24	15.0
Cypress, cut one year	.66	41.2
Ebony	1.13	70.5
Elder pith	.076	4.74
Elm	.55–.67	34.3
" Green	.76	47.5
" with 20 per cent. moisture	.72	44.9
Fir, Norway Pine	.74	46.1
" Spruce	.48–.70	29.9–43.7
" Larch	.50–.64	31.2–39.9
" White Pine, Scotch	.53	34.3
" " " " with 20 per cent. moisture	.49	30.6
" Yellow Pine, American	.46	28.7
" " " English	.66	41.2
Lignum-Vitæ	.65–1.33	40.5–82.9
Mahogany, Cuba	.56–1.06	34.9
" Honduras	.56–1.06	34.9
Maple	.65–.73	40.5
" 20 per cent. moisture	.67	41.8
Mulberry	.89	55.5
Oak, American	.87	54.2
Poplar	.39	24.3
" White	.32–.51	20.0–31.8
" 20 per cent. moisture	.48	29.9
Rock-Elm	.80	50.0
Sycamore	.59	36.8
Walnut	.58	42.4
Willow	.49	30.6

Substance.	Specific Gravity.	Weight of One Cu. Ft.
	Water = 1.	Pounds.
Pearls	2.72	169.6
Coral	2.69	167.7
Ivory	1.82–1.92	114–119.7
Bone	1.80–2.00	112.2–124.7
Wool	1.61	100.4
Tendon	1.12	69.8
Cartilage	1.09	68.0
Human Body	1.07	66.7
Nerve	1.04	64.9
Beeswax	.96	59.9
Lard	.95	59.3
Spermaceti	.94	58.8
White of Whalebone	.94	58.7
Butter	.94	58.7
Pork Fat	.94	58.7
Tallow	.92	57.5
Beef Fat	.92	57.5
Mutton Fat	.92	57.4
VEGETABLE SUBSTANCES:—		
Cotton	1.95	121.6
Flax	1.79	111.6
Starch	1.53	95.4
Sugar	1.005	.....
Gutta-percha	.97	60.5
India-rubber	.93	58.0
	Weight of One Cu. Ft., loosely filled.	Weight of One Cu. Ft., closely filled.
Grain:		
Wheat, California	49	53
Peas	50	54
Indian Corn	43½	47

LIQUIDS: SPECIFIC GRAVITY AND WEIGHT.

Liquids at 32° F.	Specific Gravity.	Weight of One Cubic Foot.	Weight of One Br. Gallon.
	Water = 1.	Pounds.	Pounds.
Mercury	13.596	848.7	136.0
Sulphuric Acid, maximum concentration	1.84	114.9	18.4
Nitrous Acid	1.55	96.8	15.5
Chloroform	1.53	95.5	15.3
Nitric acid, of commerce	1.22	76.2	12.2
Acetic acid, maximum concentration	1.08	67.4	10.8
Milk	1.03	64.3	10.3
Sea Water, ordinary	1.026	64.05	10.3
Pure Water, at 39° F.	1.000	62.425	10.0112
Wine, Red	.99	62.0	9.9
Oil, Linseed	.94	58.7	9.4
" Rapeseed	.92	57.4	9.2
" Whale	.92	57.4	9.2
" Olive	.915	57.1	9.15
" Turpentine	.87	54.3	8.7
Tar	1.00	62.4	10.0
Petroleum	.88	54.9	8.8
Naphtha	.85	53.1	8.5
Ether, Nitric	1.11	69.3	11.1
" Sulphurous	1.08	67.4	10.8
" Nitrous	.89	55.6	8.9
" Acetic	.89	55.6	8.9
" Hydrochloric	.87	54.3	8.7
" Sulphuric	.74	44.9	7.2
Alcohol, proof spirit	.92	57.4	9.2
" pure	.79	49.3	7.9
Benzine	.85	53.1	8.5
Proof Spirit	.80	49.9	8.0

GASES at 32° F., and under one Atmosphere of Pressure.	Specific Gravity.	Weight of One Cubic Foot.		Volume of One Pound Weight.
	Air = 1.	Pounds.	Ounces.	Cub. Ft.
Mercury	6.9740	.563	9.008	1.776
Chloroform	5.3000	.428	6.846	2.337
Turpentine	4.6978	.378	6.042	2.637
Acetic Ether	3.0400	.245	3.927	4.075
Benzine	2.6943	.217	3.480	4.598
Sulphuric Ether	2.5860	.209	3.340	4.790
Chlorine	2.4400	.197	3.152	5.077
Sulphurous Acid	2.2470	.1814	2.902	5.513
Alcohol	1.6130	.1302	2.083	7.679
Carbonic Acid	1.5290	.12344	1.975	8.101
Oxygen	1.1056	.089253	1.428	11.205
Air	1.0000	.080728	1.29165	12.387
Nitrogen	.9701	.078596	1.258	12.723
Carbonic Oxide	.9674	.0781	1.250	12.804
Olefiant Gas	.9847	.0795	1.272	12.580
Ammoniacal Gas	.5894	.04758	7.613	21.017
Light Carbureted Hydrogen	.5527	.04462	.7139	22.412
Coal Gas	.4381	.03536	.5658	28.279
Hydrogen	.0692	.005592	.0895	178.83

WEIGHT AND VOLUME OF BODIES.
(Tod.)

BODIES.	Weight of One Cubic Foot.		Weight of One Cubic Inch.	Cubic Inches in One Pound.
METALS.	Oz.	Lb.	Oz.	Cub. In.
Antimony, cast	6,702	418.8750	3.8748	3.8866
Zinc, cast	7,190	449.3750	4.1608	3.8431
Iron, cast	7,207	450.4375	4.1707	3.8364
Tin, cast	7,291	455.6875	4.2193	3.7920
" hardened	7,299	456.1875	4.2239	3.7878
Pewter	7,471	466.9375	4.3234	3.7007
Iron, bar	7,788	486.7500	4.5069	3.5500
Cobalt, cast	7,811	488.1875	4.5202	3.5396
Steel, hard	7,816	488.5000	4.5231	3.5373
" soft meteoric	7,833	489.5625	4.5329	3.5296
Iron, hammered	7,965	497.8125	4.6093	3.4792
Nickel, cast	8,279	517.4375	4.7910	3.3395
Brass, cast	8,395	524.6875	4.8582	3.2933
" wire	8,544	534.0000	4.9444	3.2359
Nickel, hammered	8,666	541.6250	5.0150	3.1903
Gun-metal	8,784	549.0000	5.0833	3.1476
Copper, cast	8,788	549.2500	5.0856	3.1461
" wire	3,878	554.8750	5.1377	3.1140
" coin	8,915	557.1875	5.1591	3.0959
Bismuth, cast	9,822	613.8750	5.6840	2.8149
Silver, hammered	10,510	656.8750	6.0821	2.6306
" coin	10,534	658.3750	6.0960	2.6246
" pure, cast	10,744	671.5000	6.2175	2.5733
Rhodium	11,000	687.5000	6.3657	2.5134
Lead, cast	11,352	709.5000	6.3694	2.4355
Palladium	11,800	737.5000	6.8287	2.5134
Mercury (quicksilver) common	13,568	848.0000	7.8518	2.0377
" " pure	14,000	875.0000	8.1018	1.9748
Gold, trinket	15,709	981.8125	9.0908	1.7600
" coin	17,647	1,102.9375	10.2123	1.6124
" pure, cast	19,258	1,203.6250	11.1446	1.4856
" hammered	19,316	1,210.0625	11.2042	1.4280
Platinum, pure	19,500	1,218.7500	11.2847	1.4178
" hammered	20,336	1,271.0000	11.7685	1.3595
" wire	21,041	1,315.0625	12.1765	1.3140
" laminated	22,069	1,379.3125	12.7714	1.2528
Iridium, hammered	23,000	1,437.5000	13.3101	1.2021

—Clark's Mechanical Engineer's Pocket Book.

Tables showing a comparison of the degrees of Baumé, Cartier, and Beck's Areometers, with specific gravity degrees.

For Liquids Lighter than Water.

Degrees of Baumé, Cartier, Beck.	Baumé. Sp. Gr.	Cartier. Sp. Gr.	Beck. Sp. Gr.
0	....	....	1.0000
1	....	....	0.9941
2	....	....	0.9883
3	....	....	0.9826
4	....	....	0.9770
5	....	....	0.9714
6	....	....	0.9659
7	....	....	0.9604
8	....	....	0.9550
9	....	....	0.9497
10	1.000	....	0.9444
11	0.993	1.000	0.9392
12	0.986	0.992	0.9340
13	0.979	0.985	0.9289
14	0.973	0.977	0.9239
15	0.967	0.969	0.9189
16	0.960	0.962	0.9139
17	0.954	0.955	0.9090
18	0.948	0.948	0.9042
19	0.942	0.941	0.8994
20	0.935	0.934	0.8947
21	0.929	0.927	0.8900
22	0.924	0.920	0.8854
23	0.918	0.914	0.8808
24	0.912	0.908	0.8762
25	0.906	0.901	0.8717
26	0.901	0.895	0.8673
27	0.895	0.889	0.8629
28	0.889	0.883	0.8585
29	0.884	0.877	0.8542
30	0.879	0.871	0.8500
31	0.873	0.865	0.8457
32	0.868	0.859	0.8415
33	0.863	0.853	0.8374
34	0.858	0.848	0.8333
35	0.853	0.842	0.8292
36	0.848	0.837	0.8252
37	0.843	0.831	0.8212
38	0.838	0.826	0.8173
39	0.833	0.820	0.8133
40	0.829	0.815	0.8095
41	0.824	0.810	0.8061
42	0.819	0.805	0.8018
43	0.815	0.800	0.7981
44	0.810	....	0.7944
45	0.806	....	0.7907
46	0.801	....	0.7871
47	0.797	....	0.7834
48	0.792	....	0.7799
49	0:788	....	0.7763
50	0.784	....	0.7727
51	0.781	....	0.7692
52	0.776	....	0.7658
53	0.771	....	0.7623
54	0.769	....	0.7589
55	0.763	....	0.7556
56	0.759	....	0.7522
57	0.755	....	0.7489
58	0.751	....	0.7456
59	0.748	....	0.7423
60	0.744	....	0.7391
61	0.740	....	0.7359
62	0.736	....	0.7328

For Liquids Heavier than Water.

Degrees of Baumé, Beck.	Baumé. Sp. Gr.	Beck. Sp. Gr.
0	1.000	1.0000
1	1.007	1.0059
2	1.014	1.0119
3	1.020	1.0180
4	1.028	1.0241
5	1.034	1.0303
6	1.041	1.0366
7	1.049	1.0429
8	1.057	1.0494
9	1.064	1.0559
10	1.072	1.0625
11	1.080	1.0692
12	1.088	1.0759
13	1.096	1.0828
14	1.104	1.0897
15	1.113	1.0968
16	1.121	1.1039
17	1.130	1.1111
18	1.138	1.1184
19	1.147	1.1258
20	1.157	1 1333
21	1.166	1.1409
22	1.176	1.1486
23	1.185	1.1565
24	1.195	1.1644
25	1.205	1.1724
26	1.215	1.1806
27	1.225	1.1888
28	1.235	1.1972
29	1.245	1.2057
30	1.256	1.2143
31	1.267	1.2230
32	1.278	1.2319
33	1.289	1.2409
34	1.300	1.2500
35	1.312	1.2593
36	1.324	1.2680
37	1.337	1.2782
38	1.349	1.2879
39	1.361	1.2977
40	1.375	1.3077
41	1.388	1.3178
42	1.401	1.3281
43	1.414	1.3386
44	1.428	1.3492
45	1.442	1.3600
46	1.456	1.3710
47	1.470	1.3821
48	1.485	1.3934
49	1.500	1.4050
50	1.515	1.4167
51	1.531	1.4286
52	1.546	1.4407
53	1.562	1.4530
54	1.578	1.4655
55	1.596	1.4783
56	1.615	1.4912
57	1.634	1.5044
58	1.653	1.5179
59	1.671	1.5315
60	1.690	1.5454
61	1.709	1.5596
62	1.729	1.5741
63	1.750	1.5888
64	1.771	1.6038

UNITS OF LOG MEASURE.

In the United States and Canada logs are most commonly measured in board feet. Firewood and wood cut into short bolts, such as small pulpwood, excelsior wood, etc., are usually measured in cords. In the Adirondack Mountains the 19-inch standard, or, as it is often called, "the market," is a common unit of log measure. In some localities a log 22 inches in diameter at the small end and 13 feet long is used as a standard log and is the unit for buying and selling timber. In other sections standards are used which are based on logs 12 feet long and respectively 21, 22, and 24 inches in diameter at the small end inside the bark.

In some cases logs are measured in cubic feet. This is common with long spar timber and with long logs to be cut or hewn square. In many localities timber is sold by the log or tree, and in some sections standing timber is sold for a specified amount per acre or other unit of land measure. Piles and mine props are usually sold by the piece or by the linear foot. Logs are occasionally sold by the ton.

BOARD MEASURE.

The unit of board measure is the board foot, which is the contents of a board 1 foot square and 1 inch thick. The number of board feet which can be sawed from logs of different diameters and lengths is shown in log rules.

Logs are usually measured at the small end inside the bark, because the removal of the slabs reduces the logs to the dimensions of the small end. This is the custom in measuring short logs by all the rules which are used, except in certain cases. Some of the rules, for example the Doyle and the Partridge rules, were intended by their originators to be used for an average diameter, but most persons who use them take the diameter at the small end, except in case of long timber. In measuring long logs which are to be cut into short logs before being sawed into boards, the diameter is usually not taken at the small end alone. Thus in using the Maine Rule, long logs are scaled as two logs. The diameter at the small end inside the bark is measured and is taken as the diameter of the uppermost log. The diameter at the small end of the lower log is estimated by the log-scaler. Another method of measuring long logs, often used with the Doyle Rule, is to take the diameters at both ends inside the bark, average them, and use this average as the diameter of the log. Still another method in use is to take the diameter inside the bark, one-third the distance from the small end of the log.

Logs are usually cut from 2 to 6 inches longer than the standard lengths of boards, to allow for bruising in handling. This additional length is disregarded in scaling.

Log rules give the number of board feet in logs which are straight and sound. If logs are unsound or otherwise defective, a certain allowance must be made by the scaler. The determination of the amount in board feet which should be deducted for unsoundness or defects in a given log requires great skill on the part of the scaler, and, as it is a matter of judgment in each case, no definite directions can be given.

CORD MEASURE.

Firewood, small pulpwood, and material cut into short sticks for excelsior, etc., is usually measured by the cord. A cord is 128 cubic feet of stacked wood. The wood is usually cut into 4-foot lengths, in which case a cord is a stack 4 feet high and 8 feet long. Sometimes, however, pulpwood is cut 5 feet long, and a stack of it 4 feet high and 8 feet long is considered 1 cord. In this case the cord contains 160 cubic feet of stacked wood. In localities where firewood is cut in 5-foot lengths a cord makes a stack 4 feet high and 6½ feet long, and contains 130 cubic feet of stacked wood. Where it is desirable to use shorter lengths for special purposes, the sticks are often cut 1½, 2, and even 3 feet long. A stack of such wood, 4 feet high and 8 feet long, is considered 1 cord, but the price is always made to conform to the shortness of the measure.

A cord foot is one-eighth of a cord. A cord foot is a stack of 4-foot wood 4 feet high and 1 foot long. Farmers frequently speak of a foot of cord wood, meaning a cord foot. By the expression "surface foot" is meant the number of square feet measured on the side of a stack.

In some localities, particularly in New England, cord wood is measured by means of calipers. Instead of stacking the wood and computing the cords in the ordinary way, the average diameter of each log is determined with calipers and the number of cords obtained by consulting a table which gives the amount of wood in logs of different diameters and lengths, expressed in so-called cylindrical feet. A cylindrical foot is one one-hundred and twenty-eighth of a cord. A better term would be "stacked cubic foot," as it represents a cubic foot of stacked wood, as opposed to a cubic foot of solid wood. The number of cylindrical or stacked cubic feet in a log is computed by squaring the average diameter of the log in inches, multiplying by the length of the log in feet, and dividing the result by 144.

Some tables give the results in feet and inches (cylindrical or stacked cubic, not linear feet)

A special caliper rule for measuring cord wood has been made by Mr. John Humphrey, of Keene, N. H. Instead of considering a cylindrical or stacked cubic foot equivalent to one one-hundred and twenty-eighth of a cord, he has assumed it to be equivalent to one one-hundredth of a cord. In either case the cylindrical or stacked cubic foot is a purely arbitrary unit and the final results in cords are the same.

The number of cylindrical or stacked cubic feet in the different logs is determined by means of calipers and reference to a table, or by means of the calipers alone if the results are inscribed directly upon them. The total number of cylindrical or stacked cubic feet is then divided by 128.

CONVERSION OF CORD MEASURE INTO CUBIC MEASURE.

Dealers in wood frequently wish to convert cord measure into cubic measure, and vice versa. The converting factor used depends primarily on the form of the wood. If the wood is split, there is more solid contents in a stacked cord than if the wood is in

round sticks. There is more wood in a given stack if the sticks are smooth and straight than if they are rough and crooked. The converting factor depends, further, on the character of the stacking. If the wood is skillfully stacked there is more solid contents than when the work is poorly done. It has been found in Europe through a series of careful measurements that a stack of wood may be reduced to solid cubic measure by multiplying the number of cubic feet by the following factors:

For split firewood. 0.7
For small round firewood. 6

Thus, a cord of split firewood is equivalent to 128 cubic feet multiplied by 0.7, which equals 89.6 cubic feet. To convert a given number of cords into solid cubic feet, multiply by 128 and then multiply the product by 0.7 or 0.6, according as the wood is split or consists of small round sticks; or multiply directly by 89.6.

To convert a given number of solid cubic feet into cords, divide by 128 and then divide the result by 0.7 or 0.6, according to the form of the wood; or divide directly by 89.6. If the stacking is very poor or if the wood is rough and crooked, the figures must be modified.

No rule can be given for converting cord measure into board measure. Lumbermen assign to a cord of wood values varying from 500 to 1,000 board feet. So much depends upon the quality of the wood, the purpose for which it is to be used, the method of piling, etc., that no constant converting factor can be given.

Bark is piled in stacks and measured in the same way as firewood.

CONVERSION OF CUBIC MEASURE INTO BOARD MEASURE.

The ratio between the number of board feet and cubic feet in logs depends on the species of tree, on the size of the logs, and on the method of scaling. The ratio for standing trees depends, further, on the minimum size of the merchantable log. For example, the ratio would be different, if 4 logs were cut from a tree, from the result if only 3 logs were taken. Satisfactory figures can, therefore, be obtained only by comparing the scales of logs and trees actually measured in the woods. Such tables are now being prepared by the Bureau of Forestry for different species in different regions.

MEASUREMENT OF SAWED LUMBER—BOARD MEASURE.

The superficial measure of inch boards is obtained by multiplying the width in inches by the length in feet and dividing by 12. Tables showing the contents of boards of different widths and lengths are published in practically every lumberman's ready reckoner, of which there are many on the market.

The contents of boards thicker than 1 inch are obtained by multiplying the width in inches by the thickness in inches and the product by the length in feet, and then dividing by 12.—*The Woodman's Handbook.*

HARDNESS OF MINERALS:

1. Talc.
2. Rock Salt. } Scratched by finger nail.
3. Calcite
4. Fluor
5. Apatite
6. Orthoclase } Scratched by a knife blade.
7. Quartz
8. Topaz
9. Corundum } May be roughly distinguished by a file.
10. Diamond.

HEAT—ITS MECHANICAL EQUIVALENT.

Heat is a peculiar motion of the particles of matter which prevents their contact. Heat and mechanical power are convertible forms of energy The energy of the heat that raises one pound of water 1° F. will lift a weight of 778 lbs. one foot. The power of a weight of 778 lbs. descending one foot, if applied to a small paddle-wheel turning in one pound of water, will, by friction, raise the temperature of the water 1° F.

A heat-unit is the amount of heat that raises a pound of water 1° F., or that lifts a weight of 778 lbs. one foot.

The mechanical equivalent of a heat-unit is the power of a weight of 778 lbs. descending one foot, or of a one-pound weight descending 778 feet. Hence,

778 foot-pounds = 1 heat-unit.
1 heat-unit = 778 foot-pounds.

A galvanic battery that produces an electrical current capable of heating one pound of water 1° F., will yield magnetic force sufficient to raise a weight of 778 lbs. one foot high.

Thus heat, electricity, magnetism, and chemical force are brought into numerical correlation with mechanical power.

The illustrious philosopher, Dr. J. P. Joule, of Manchester, England, first measured accurately the mechanical equivalent of heat, A.D. 1845.

Heat of Metals.—A metal is an element possessing a luster, and the higher oxides of which only are acid-forming compounds. Metals have the following properties: A specific gravity usually greater than one. The specific heat is less than unity, and this heat varies inversely as the atomic weight of that element. The conductivity of the metals is greater than that of either the non-metals or their compounds.

The influence of heat upon metals is very varied; some melt at a low temperature, others require a red heat, a strong red, or a white heat respectively, to melt them. The following table, by Pouillet, will explain the temperatures corresponding to different colors.

Heat Color.	Corresponds to	
Incipient red heat. . . .	525° C.	977° F.
Dull red.	700	1,292
Incipient cherry red. . .	800	1,472
Cherry red.	900	1,652
Clear cherry red.	1,000	1,832
Deep orange.	1,100	2,012
Clear orange.	1,200	2,192
White.	1,300	2,372
Bright white.	1,400	2,552
Dazzling white.	1,500	2,732

STEAM PRESSURE AND TEMPERATURE.

Pressure in Lbs. per Sq. In.	Corresponding Temperature, Fahrenheit.	Pressure in Lbs. per Sq. In.	Corresponding Temperature, Fahrenheit.	Pressure in Lbs. per Sq. In.	Corresponding Temperature, Fahrenheit.
10	192.4	65	301.3	140	357.9
15	212.8	70	306.4	150	363.4
20	228.5	75	311.2	160	368.7
25	241.0	80	315.8	170	373.6
30	251.6	85	320.1	180	378.4
35	260.9	90	324.3	190	382.9
40	269.1	95	328.2	200	387.3
45	276.4	100	332.0	210	391.5
50	283.2	110	339.2	220	395.5
55	289.3	120	345.8	230	399.4
60	295.6	130	352.1	240	403.1

TABLE OF TEMPERATURE.

Degree of Fahr.	
2,786	Cast iron melts (Daniell).
1,996	Copper melts (Daniell).
1,947	Gold melts.
1,873	Silver melts (Daniell).
1,750	Brass (containing 25% of zinc) melts (Daniell).
1,000	Iron, bright cherry red (Poillet).
980	Red heat, visible in daylight (Daniell).
941	Zinc begins to burn (Daniell).
773	Zinc melts (Daniell).
644	Mercury boils (Daniell), 662 (Graham).
640	Sulphuric acid boils (Magrignac), 620 (Graham).
630	Whale oil boils (Graham).
617	Pure lead melts (Rudberg).
600	Linseed oil boils.
518	Bismuth melts (Gmelin).
442	Tin melts (Crichton).
380	Arsenious acid volatilizes.
356	Metallic arsenic sublimes.
315	Oil of turpentine boils (Kaure).
302	Etherification ends.
257	Saturated sol. of sal ammoniac boils (Taylor).
256	Saturated sol. of acetate of soda boils.
239	Sulphur melts (Miller), 226 (Fownes).
238	Saturated sol. of nitre boils.
221	Saturated sol. of salt boils (Paris Codex).
220	Saturated sol. of alum, carb. soda, and sulph. zinc, boil.
218	Saturated sol. of chlorate and prussiate potash, boil.
216	Saturated sol. of sulph. iron, sulph. copper, nitrate of lead, boil.
214	Saturated sol. of acetate lead, sulph. and bitartrate potash, boil.
213 or (213.5)	Water begins to boil in glass.
212	Water boils in metal, barometer at 30°.

Degree of Fahr.	
211	Alloy of 5 bismuth, 3 tin, 2 lead, melts.
201	Alloy of 8 bismuth, 5 lead, 3 tin, melts (Kane).
207	Sodium melts (Regnault).
185	Nitric acid 1.52 begins to boil.
180 (about)	Starch forms a gelatinous compound with water.
176	Rectified spirit boils, benzol distils.
173	Alcohol (sp. gr. .796 to .800) boils.
151	Beeswax melts (Kane), 142 (Lepage).
150	Pyroxylic spirit boils (Scanlan).
145	White of egg begins to coagulate.
141.8	Chloroform, and ammonia of .945, boil.
132	Acetone (pyroacetic spirit) boils (Kane).
122	Mutton suet and styracin melt.
116	Bisulphuret of carbon boils (Graham).
115	Pure tallow melts (Lepage), 92 (Thomson).
112	Spermaceti and stearin of lard melt.
111	Phosphorus melts (Miller).
98	Temperature of the blood.
95	Ether (.720) boils.
95	Carbolic acid crystals become an oily liquid.
88	Acetous fermentation ceases, water boils *in vacuo*.
77	Vinous ferm. ends, acetous ferm. begins.
64.4	Oil of anise liquefies.
59	Gay Lussac's *Alcoomètre* graduated at.
55	Sirups to be kept at.
30 (about)	Olive oil becomes partially solid.
32	Water freezes.
5	Cold produced by snow 2 parts and salt 1 part.
−37.9	Mercury freezes.

—*Cooley.*

LINEAR EXPANSION OF SOLIDS AT ORDINARY TEMPERATURES.

Substance.	For 1° Fahr.	For 1° Cent.
	Length = 1.	Length = 1.
Aluminium (cast)	.00001234	.00002221
Antimony (cryst.)	.00000627	.00001129
Brass, cast	.00000957	.00001722
" English plate	.00001052	.00001894
" sheet	.00001040	.00001872
Brick, best stock	.00000310	.00000550
Bronze (Baily's). Copper, 17. Tin, 2½. Zinc, 1.	.00000986	.00001774
"	.00000975	.00001755
Cement, Roman, dry	.00000797	.00001435
Cement, Portland (mixed), pure	.00000594	.00001070
Cement, Portland, mortar, with sand	.00000656	.00001180
Concrete: cement mortar and pebbles	.00000795	.00001430
Copper	.00000887	.00001596
Ebonite	.00004278	.00007700
Glass, English flint	.00000451	.00000812
" French flint	.00000484	.00000872
" white, free from lead	.00000492	.00000886
" blown	.00000498	.00000896
" thermometer	.00000499	.00000897
" hard	.00000397	.00000714
Granite, gray, dry	.00000438	.00000789
" red "	.00000498	.00000897
Gold, pure	.00000786	.00001415
Iridium, pure	.00000356	.00000641
Iron, wrought	.00000648	.00001166
" Swedish	.00000636	.00001145
" cast	.00000556	.00001001
" soft	.00000626	.00001126
Lead	.00001571	.00002828
Marble, moist	.00000663	.00001193
" dry	.00000363	.00000654
" white Sicilian, dry	.00000786	.00001415
Marble, black Galway	.00000308	.00000554
" Carrara	.00000471	.00000848
Masonry, of brick in cement mortar: headers	.00000494	.00000890
Masonry, of brick in cement mortar: stretchers	.00000256	.00000460
Mercury (cubic expansion)	.00009984	.00017971
Nickel	.00000695	.00001251
Osmium	.00000317	.00000570
Palladium, pure	.00000556	.00001000
Pewter	.00001129	.00002033
Plaster, white	.00000922	.00001660
Platinum	.00000479	.00000863
Platinum, 90 per cent. Iridium, 10 per cent. hammered and annealed	.00000476	.00000857
Platinum, 85 per cent. Iridium, 15 per cent.	.00000453	.00000815
Porcelain	.00000200	.00000360
Quartz, parallel to major axis, t 0° to 40° C.	.00000434	.00000781
Quartz, perpendicular to major axis, t 0° to 40° C.	.00000788	.00001419
Quartz, cubic expansion at 16° C.	.00001924	.00003463
Silver, pure	.00001079	.00001943
Slate	.00000577	.00001038
Steel, cast	.00000636	.00001144
" tempered	.00000689	.00001240
Stone (sandstone), dry	.00000652	.00001174
Stone (sandstone), Rauville	.00000417	.00000750
Stone (sandstone), Caen	.00000494	.00000890
Tin	.00001163	.00002094
Wedgwood ware	.00000489	.00000881
Wood, pine	.00000276	.00000496
Zinc	.00001407	.00002532
Zinc, 8. Tin, 1.	.00001496	.00002692

—Clark's Mechanical Engineer's Pocket Book.

EXPANSION OF LIQUIDS.

The cubical expansion, or expansion of volume, of water, from 32° F. to 212° F. and upwards, is given in the following Table. The rate of expansion increases with the temperature. The expansion for the range of temperature from 32° to 212° is .0466, or fully 4½ per cent. of the volume at 32°; or an average of .000259 per degree, or $\frac{1}{3863}$ part of the volume at 32° F.

Expansion of Liquids from 32° to 212° F.

Volume at 32° = 1.

Liquid.	Volume at 212°.	Expansion.
Alcohol	1.1100	$\frac{1}{9}$
Nitric acid	1.1100	$\frac{1}{9}$
Olive oil	1.0800	$\frac{1}{12}$
Turpentine	1.0700	$\frac{1}{14}$
Sea water	1.0500	$\frac{1}{20}$
Water	1.0466	$\frac{1}{22}$
Mercury	1.018	$\frac{1}{55}$

FRICTION.—The ratio obtained by dividing the entire force of friction by the normal pressure is called the coefficient of friction. The unit or coefficient of friction is the friction due to a normal pressure of one pound:

Iron on oak	0.62
Cast iron on oak	0.49
Oak on oak, fibres parallel	0.48
Oak on oak, greased	0.10
Cast iron on cast iron	0.15
Wrought iron on wrought iron	0.14
Brass on iron	0.16
Brass on brass	0.20
Wrought iron on cast iron	0.19
Cast iron on elm	0.19
Soft limestone on the same	0.64
Hard limestone on the same	0.38
Leather belts on wooden pulleys	0.47
Leather belts on cast-iron pulleys	0.28
Cast iron on cast iron, greased	0.10

Pivots or axes of wrought or cast iron, on brass or cast-iron pillows:

First, when constantly supplied with oil	0.05
Second, when greased from time to time	0.08
Third, without any application	0.15

STRENGTH OF MATERIALS.

METALS.

Name of Metal.	Tensile Strength in Pounds per Sq. In.
Aluminum wire	30,000–40,000
Brass wire, hard drawn	50,000–150,000
Bronze, phosphor, hard drawn	110,000–140,000
" silicon " "	95,000–115,000
Copper wire, hard drawn	60,000–70,000
Gold * wire	38,000–41,000
Iron, † cast	13,000–29,000
" wire, hard drawn	80,000–120,000
" " annealed	50,000–60,000
Lead, cast or drawn	2,600–3,300
Palladium *	39,000
Platinum * wire	50,000
Silver * wire	42,000
Steel, mild, hard drawn	100,000–200,000
" hard " "	150,000–330,000
Tin, cast or drawn	4,000–5,000
Zinc, cast	7,000–13,000
" drawn	22,000–30,000

STONES AND BRICKS.

Name of Substance.	Resistance to Crushing in Pounds per Sq. In.
Basalt	18,000–27,000
Brick, soft	300–1,500
" hard	1,500–5,000
" vitrified	9,000–26,000
Granite	17,000–26,000
Limestone	4,000–9,000
Marble	9,000–22,000
Sandstone	4,500–8,000
Slate	11,000–30,000

TIMBER.

Name of Wood	Tensile Strength in Pounds per Sq. In.	Resistance to Crushing in Pounds per Sq. In.
Ash	11,000–21,000	6,000–9,000
Beech	11,000–18,000	9,000–10,000
Birch	12,000–18,000	5,000–7,000
Chestnut	10,000–13,000	4,000–6,000
Elm	12,000–18,000	6,000–10,000
Hackberry	10,000–16,000	......
Hickory	15,000–25,000	7,000–12,000
Maple	8,000–12,000	6,000–8,000
Mulberry	8,000–14,000	......
Oak, burr	15,000–20,000	7,000–10,000
" red	13,000–18,000	5,000–7,000
" water	12,000–16,000	4,000–6,000
" white	20,000–25,000	6,000–9,000
Poplar	10,000–15,000	5,000–8,000
Walnut	8,000–14,000	4,000–8,000

* On the authority of Wertheim.

† The crushing strength of cast iron is from 5.5 to 6.5 times the tensile strength.

NOTES.—According to Boys, quartz fibers have a tensile strength of between 116,000 and 167,000 pounds per square inch.

Leather belting of single thickness bears from 400 to 1,600 pounds per inch of its breadth. —*Smithsonian Tables.*

WATER.

1 U. S. gallon equals 231 cubic inches; .1337 cubic foot; 8.333 pounds of water at 62° F.; 3.786 liters.

1 cubic inch of water at 62° F. equals .03608 pound; .5773 ounce; 252.6 grains; .004326 U. S. gallon; .01638 liter.

1 cubic foot of water at 62° F. equals 62.355 pounds; 997.68 ounces (about 1000); .557 cwt. (of 112 pounds); .0278 long ton; 7.4805 U. S. gallons; 28.315 liters; .02832 cubic meter.

1 cylindrical inch of water at 62° F. equals .02833 pound; .4533 ounce; .7854 cubic inch.

1 cylindrical foot of water at 62° F. equals 48.973 pounds (about 50); 783.57 ounces; .437 cwt. (of 112 pounds); .0219 long ton; 5.8758 U. S. gallons; 22.2380 liters; .02224 cubic meter.

1 cubic yard of water equals 1,684.8 pounds; 15.043 cwt. (of 112 pounds), or 15 cwt. 4.8 pounds; .7645 cubic meter.

1 liter of water equals 2.2046 pounds at 62° F.; .2641 U. S. gallon; 61.025 cubic inches; .0353 cubic foot.

1 cubic meter of water equals 1 metric ton, or 1,000 kilograms at 39.1° F. or 4° C.; 2,204.62 pounds at 39.1° F. or 4° C.; 2,203.7 pounds at 62.4 pounds per cubic foot; 1 ton of 2,240 pounds, nearly; 1 tun of 4 hogsheads, or 2,100 pounds, nearly; 264.2 U. S. gallons; 1.308 cubic yards; 35.3156 cubic feet; 1,000 liters.

The weight of fresh water is commonly assumed, in ordinary calculations, to be 62.4 pounds per cubic foot, which is the weight at 52.3° F. It is frequently taken as 62½ pounds or 1,000 ounces per cubic foot.

The volumes of given weights of water, at the rate of 62.4 pounds per cubic foot, are as follows:

1 ton (long), 35.90 cubic feet (about 36); 1 cwt. (of 112 pounds), 1.795 cubic feet; 1 pound, .016 cubic feet or 27.692 cubic inches; 1 ounce, 1.731 cubic inches; 1 metric ton, at 39.1° F. or 4° C., 35.3156 cubic feet; 1 kilogram, at 39.1° F. or 4° C., .0353 cubic feet or 61.025 cubic inches; 1 metric ton, at 52.3° F. (62.4 pounds per cubic foot), 35.330 cubic feet.

A pipe 1 yard in length holds about as many pounds of water at ordinary temperatures as the square of its diameter in inches (about two per cent. more).

A column of water at 62° F., 1 foot high, is equivalent to a pressure of .433 pound or 6.928 ounces per square inch of base; or to 62.355 pounds per square foot.

A column of water 1 inch high is equivalent to a pressure of .5773 ounce or .03608 pound per square inch; or to 5.196 pounds per square foot.

A column of water 100 feet high is equivalent to 43¼ pounds per square inch; or 2.786 tons per square foot.

A column of water 1 mile deep, weighing 62.4 pounds per cubic foot, is equivalent to a pressure of about 1 ton per square inch.

1 pound per square inch is equivalent to a column of water at 62° F. 2.31 feet or 27.72 inches high.

SEA WATER.

1 cubic foot at 62° F., 64 pounds; 1 cubic yard, 15½ cwt., nearly (8 pounds less); 1 cubic meter, 1 long ton, fully (20 pounds more); 1 ton, 35 cubic feet.

Ratio of weight of fresh water to that of sea water, 39 to 40, or 1 to 1.028.

ICE AND SNOW.

1 cubic foot of ice at 32° F., 57.50 pounds; 1 pound of ice at 32° F., .0174 cubic foot, or 30.067 cubic inches; specific density of ice, .922; that of water at 62° F. being 1.

AIR.

1 cubic foot, at 14.7 lbs. per square inch, or 1 atmosphere, equals .080728 lb. at 32° F.; 1.29 ounce at 32° F.; 565.1 grains at 32° F.; .076097 lb. at 62° F.; 1.217 ounce at 62° F.; 532.7 grains at 62° F.

1 liter, under 1 atmosphere, equals 1.293 grams at 32° F.; 19.955 grains at 32° F.

1 lb. of air at 62° F. equals 13.141 cubic feet.

The weights of equal volumes of mercury, water, and air. at 62° F. under 1 atmosphere, are as 11,140.56, 819.4, and 1.

1 atmosphere of pressure equals 14.7 lbs. per square inch; 2,116.4 lbs. per square foot; 1.0335 kilograms per square centimeter; 29.922 inches of mercury at 32° F.; 76 centimeters of mercury at 32° F.; 30 inches of mercury at 62° F.; 33.947 feet of water at 62° F.; 10.347 meters of water at 62° F.

1 lb. per square inch equals 2.035 inches of mercury at 32° F.; 51.7 millimeters of mercury at 32° F.; 2.04 inches of mercury at 62° F.; 2.31 feet of water at 62° F.; 27.72 inches of water at 62° F.

1 ounce per square inch equals 1.732 inches of water at 62° F.

1 lb. per square foot equals .1925 inch of water at 62° F.; .01417 inch of mercury at 62° F.

STRENGTH OF ICE.

Ice 2 in. thick will bear infantry.

Ice 4 in. thick will bear cavalry or light guns.

Ice 6 in. thick will bear heavy field guns.

Ice 8 in. thick will bear 24-pounder guns on sledges; weight not over 1,000 lbs. to a square foot.

WEIGHT OF BALLS.

$$W = \frac{D^3 + 00}{C};$$

$$D = \sqrt[3]{W \times C - 00.}$$

When D = diameter of ball in inches;
W = weight of ball in lbs.;
C = aconstant = 733 for cast iron;
= 464 for lead;
= 595 for copper;
= 635 for brass.

or,

$$W = D^3 \times C;$$

$$D = \sqrt[3]{W \times C.}$$

When C = a constant = 0.1364 for cast iron;
= 0.2155 for lead;
= 0.168 for copper;
= 0.1574 for brass.

Weight of cast-iron balls.

$$W = \left(\frac{D}{2}\right)^3 \times 0.1.$$

To find nominal horse-power of boiler required for direct-acting steam-pumps.

$$NHP = \frac{D^2 - \text{the last figure}}{2}.$$

When NHP = nominal horse-power;
D = diameter of steam cylinder in inches.

PIPES.

Usual inclination of pipes.

1 in. in	12 ft.	= minimum fall for house drains;
1 " "	16 "	= minimum fall for land drains;
1 " "	40 "	= minimum fall for sub-drains for houses;
1 " "	100 "	= minimum fall for main drains for houses;
1 " "	150 "	= fall of mountain torrents;
1 " "	230 "	= " " rivers and rapid currents;
1 " "	280 "	= fall of strong currents;
1 " "	340 "	= " " ordinary rivers with good current;
1 " "	440 "	= fall of winding rivers subject to inundations with slow current;
1 " "	480 "	= fall of water channels, supply pipes to reservoirs and small canals;
1 " "	570 "	= fall of large canals;
1 " "	1,000 "	= very slow current, approaching to stagnant water.

Discharge through pipes.

Discharge in 24 hours divided by 1,440 = discharge per min.; discharge in cubic feet per minute × 9,000 = imperial gallons per day of 24 hours; discharge in cubic feet per minute × 11,000 = U. S. gallons per day of 24 hours; discharge in cubic feet per second × 2.2 = cubic yards per minute; discharge in cubic feet per second × 6.24 = imperial gallons per second; discharge in cubic feet per second × 7.48 = U. S. gallons per second; discharge in cubic feet per second × 133 = cubic yards per hour; discharge in cubic feet per second × 375 = imperial gallons per minute; discharge in cubic feet per second × 450 = U. S. gallons per minute; discharge in cubic feet per second × 2,400 = long tons per day of 24 hours; discharge in cubic feet per second × 2,700 = short tons per day of 24 hours; velocity in feet per second × 0.68 = mile per hour; velocity in feet per second × 60 = feet per minute; velocity in feet per second × 20 = yards per minute; pressure head of water in feet = pressure of water in lbs. per square foot × 0.016; pressure of water in lbs. per square foot = head in feet × 62.32.

ANIMAL POWER—HORSE.

A horse walking in a circle at a speed of 176 feet per minute will raise with a common deep-well pump—

4 h. per day 1,653 gals. per min.; 1 ft. high.
5 " " " 1,480 " " " " " "
6 " " " 1,350 " " " " " "
8 " " " 1,160 " " " " " "
10 " " " 1,040 " " " " " "

Tractive force of a horse when working 8 hours a day on a well-made road and walking at a rate of 2½ miles per hour, 150 lbs.

Tractive force of a horse when working a lift or horse-run with intervals of rest between each movement, the day's work not to exceed 6 hours, 300 lbs.

Tractive force of a horse when working in a circle of 30 feet diameter in working a mill for 8 hours per day at a pace of 2 miles per hour, 100 lbs.

A horse can exert a force horizontally at a dead pull, 400 lbs.

A horse can carry on his back a distance of 20 miles per day on a well-made road, without overexertion, from 250 to 300 lbs.

The horse-power adopted as a unit in estimating the force of a steam-engine = 33,000 lbs. raised 1 foot high in 1 minute, an amount of force which few horses could perform for any length of time.

MANUAL POWER.

Duration of work = 1 day of 8 to 10 hours.

Description of Work	Mean Effect in Lbs.	Velocity in Feet per Minute.	Lbs. Raised 1 Foot High per Minute.
Lifting weights by hand breast high	40	25	1,000
Raising water from a well by a bucket and rope.	30	35	1,050
Lifting a weight by a rope and overhead tackle.	40	30	1,200
Working a hand pump.	30	60	1,800
Drawing a canal boat.	12	160	1,920
Working a ship's capstan.	25	100	2,500
Turning the crank of a winch.	15	200	3,000
Rowing a boat.	40	80	3,200

The efforts in the above table, although extending over 8 or 10 hours, exclusive of meal-times, per day, are not altogether continuous, but include the usual intervals of rest or diminished exertion peculiar to each class of work.

WINDMILLS.

To find the horse-power of a wind-engine.

$$HP = \frac{A \times V^2}{1,100,000}.$$

When HP = effective horse-power;
A = area of sails in square feet;
V = velocity of the wind in feet per second.

To find the area of sails required for a given horse-power.

$$A = \frac{HP \times 1,100,000}{V^2}.$$

The best effect is obtained when the total surface of the sails presented to the wind does not cover more than three-quarters of the surface of the whole disk described by the radial arms or whips.

To find the force of wind.

$$P = 0.002288\ V^2;$$
$$P = 0.00422\ V_1^2;$$
$$P = 0.0023\ V^2 \times \sin X.$$

When P = pressure in lbs. per square foot;
V = velocity in feet per second;
V_1 = velocity in miles per hour;
X = angle of incidence of direction of the wind with the plane of the surface when it is oblique.

To find the angle of the sails.

$$a = 23° - \frac{18D^2}{R^2}.$$

When a = angle of the sail with the plane of motion at any part of the sail;
D = distance of any part of the sail from the axis in feet;
R = total radius of sail in feet.

To find angle of shaft with horizon.

a = 8 degrees on level ground;
= 15 degrees on high ground.

To find breadth of whip.

$$B = \tfrac{1}{30}W;$$
$$D = \tfrac{1}{40}W;$$
$$B_1 = \tfrac{1}{60}W;$$
$$D_1 = \tfrac{1}{80}W;$$
$$W_1 = \tfrac{1}{3}W.$$

When W = length of whip in feet;
W_1 = width of sail in feet;
B = breadth of whip at axis in feet;
D = depth of whip at axis in feet;
B_1 = breadth of whip at tip in feet;
D_1 = depth of whip at tip in feet;

Divided by the whip in the proportion of 5 to 3, the narrow portion being nearest to the wind.

$$W_{11} = \tfrac{1}{5}W;$$
$$D_{11} \neq \tfrac{1}{7}W.$$

When W_{11} = width of sail at axis;
D_{11} = distance of sail from axis.

Cross-bars from 16 to 18 inches apart.

Velocity of tip of sails = 2.6 V, nearly.

In examining the ratio between the velocity of *the wind and the number of revolutions* of the wheel-shaft Mr. Smeaton obtained the result in table below, for Dutch sails, in their common position, when the radius of the wheel was 30 feet:

Number of Revolutions of Wheel-shaft per Minute.	Velocity of Wind in an Hour.	Ratio between Velocity of the Wind and Revolutions of Wheel-shaft.
3	2 miles	0.666
5	4 "	0.800
6	5 "	0.833

The most efficient angles.

Part of Radius which is Divided in Six Parts.	Angle with the Axis.	Angle of Weather.
1	72°	18°
2	71°	19°
3	72°	18° middle.
4	74°	16°
5	77½°	12½°
6	83°	7°

Supposing the radius of the sail to be 30 feet, then the sail will commence at 1/6th, or 5 feet from the axis, where the angle of inclination will be 72°, at 2/6ths or 10 feet from the axis will be 71°, and so on.

In order to utilize the maximum effect of wind, therefore, it is necessary to load the wind-engine so that the number of revolutions of the wheel is proportional to the velocity of the wind.

To find proper number of revolutions of a wind-mill.

$$N = \frac{3.16 \times V}{L \times \sin U};$$

if $U = 16°$,

$$N = \frac{11.5\ V}{L};$$

When N = number of revolutions of wheel per minute;
V = velocity of the wind in feet per second;
$L = \sqrt{\frac{R^2 + R_1^2}{2}}$ = radius of center of percussion in feet;
R = extreme radius of wheel in feet;
R_1 = inner radius of wheel in feet;
U = mean angle of sails to the plane of motion.

FORCE OF WIND WHEN BLOWING PERPENDICULARLY UPON A SURFACE OF ONE SQUARE FOOT.

Velocity of Wind.			Perpendicular Force on One Square Foot in Lbs.	Description.
Miles per Hour.	Feet per Minute.	Feet per Second.		
1	88	1.47	.005	Hardly perceptible
2	176	2.93	.020	Just perceptible
3	264	4.40	.044	" "
4	352	5.87	.079	Gentle breeze
5	440	7.33	.123	" "
10	880	14.67	.492	Pleasant
15	1,320	22.00	1.107	"
20	1,760	29.30	1.968	Brisk gale
25	2,200	36.60	3.075	" "
30	2,640	44.00	4.428	High wind
35	3,080	51.30	6.027	" "
40	3,520	58.60	7.872	Very high wind
45	3,960	66.00	9.963	" " "
50	4,400	73.30	12.300	Storm
60	5,280	88.00	17.712	Great storm
70	6,160	102.7	24.108	" "
80	7,040	117.3	31.488	Hurricane
100	8,800	146.6	49.200	"

—Whittaker's Mechanical Engineer's Pocket Book.

METALS: WEIGHTS FOR VARIOUS DIMENSIONS.

Metal.	Specific Weight.	Weight of One Cubic Foot.	Weight of One Square Foot.			Weight of One Linear Foot 1 In. Sq.	Weight of One Cubic Inch.
			1 Inch Thick.	⅛ Inch Thick.	1/10 Inch Thick.		
	Wrought Iron = 1.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Aluminum, wrought . .	.348	167	13.92	1.74	1.39	1.160	.097
" cast.	.333	160	13.33	1.67	1.33	1.111	.092
Antimony.	.879	418	34.83	4.35	3.48	2.902	.242
Bismuth.	1.285	617	51.42	6.42	5.14	4.283	.357
Brass, cast.	1.052	505	42.08	5.26	4.21	3.507	.292
" sheet.	1.098	527	43.92	5.49	4.39	3.652	.304
" yellow.	1.079	518	43.17	5.40	4.32	3.597	.298
" Muntz metal.	1.062	511	42.58	5.32	4.26	3.549	.296
" wire.	1.110	533	44.42	5.55	4.44	3.701	.308
Bronze, gun-metal.	1.106	531	44.25	5.54	4.43	3.688	.307
" mill bearings. . .	1.133	544	45.33	5.66	4.53	3.780	.315
" small bells.	1.004	482	40.17	5.04	4.02	3.347	.279
" speculum metal. .	.969	465	38.75	4.84	3.88	3.299	.269
Copper, sheet	1.114	549	45.75	5.72	4.58	3.813	.318
" hammered.	1.158	556	46.33	5.79	4.63	3.861	.322
" wire.	1.154	554	46.17	5.77	4.62	3.778	.315
Gold.	2.500	1200	100.00	12.50	10.00	8.333	.694
Iron, cast.	.937	450	37.50	4.69	3.75	3.125	.260
" wrought.	1.000	480	40.00	5.00	4.00	3.333	.278
Lead, sheet.	1.483	712	59.33	7.41	5.93	4.944	.412
Manganese.	1.040	499	41.58	5.20	4.16	3.465	.289
Mercury.	1.769	849	70.75	8.84	7.07	5.896	.491
Nickel, hammered.	1.127	541	45.08	5.64	4.51	3.757	.313
" cast.	1.075	516	43.00	5.37	4.30	3.583	.299
Platinum.	2.796	1342	111.83	13.97	11.18	9.320	.777
Silver.	1.365	655	54.58	6.82	5.46	4.549	.379
Steel.	1.020	490	40.83	5.12	4.10	3.403	.284
Tin.	.962	462	38.50	4.81	3.85	3.208	.268
Zinc, sheet.	.935	449	37.42	4.67	3.74	3.118	.260
" cast.	.892	428	35.67	4.46	3.57	2.972	.248

—Clark's Mechanical Engineer's Pocket Book.

BOILER TUBES.

The following table gives the draught area and heating surface of the various-sized boiler tubes and flues:

External Diameter.	Draught Area in Square Inches.	Draught Area in Square Feet.	Outside Heating Surface in Feet per Foot of Tube in Length.	Number of Tubes in One Square Foot of Draught Area.
⅝	......	......	.1636	......
¾	......	......	.1963	......
1	.575	.0040	.2618	250.0
1¼	.968	.0067	.3272	149.3
1½	1.339	.00964	.3927	103.7
1¾	1.911	.0133	.4581	75.2
2	2.573	.0179	.5236	55.9
2¼	3.333	.0231	.5891	43.3
2½	4.083	.0284	.6545	35.2
2¾	5.027	.0349	.7200	28.7
3	6.070	.0422	.7854	23.7
3¼	7.116	.0494	.8508	20.2
3½	8.347	.0580	.9163	17.2
3¾	9.676	.0672	.9818	14.9
4	10.93	.0759	1.0472	13.2
4½	14.05	.0996	1.1781	10.2
5	17.35	.1205	1.3090	8.3
6	25.25	.1753	1.5708	5.7
7	34.94	.2426	1.8326	4.1
8	46.20	.3208	2.0944	3.1
9	58.63	.4072	2.3562	2.5
10	72.23	.5016	2.6180	2.0

TO OBTAIN INDEX OF A LATHE.

How to Obtain the Index of an Engine Lathe.—If you will note what thread the lathe will cut when two given gears are in place, you can easily construct a table that will show you just what thread any two gears will cause the lathe to cut. Suppose that two sixty-threes cause 12 threads to the inch. Then place 12 in the space A in the diagram below.

Stud.

SCREW	28	33	35	42	49	56	63	70	77	84	91	98	105	112
28														
33														
35														
42														
49					b									
56						a	C							
63						B	A	D						
70							E	c						
77									d					
84														
91														
98														
105														
112														

Now, 63 : 56 :: A : C
63 : 70 :: A : E } Direct proportion.

Also, 56 : 63 :: A : B
70 : 63 :: A : D } Inverse proportion.

The spaces may all be filled except a, b, c, d, etc., which it is useless to fill, as only your 63 gear is duplicated. A half-day's time will be sufficient for a good mathematician to fill out the table.

Nails, Memoranda Concerning.—This table will show at a glance the length of the various sizes, and the number of nails in a pound. They are rated from "3-penny" up to "20-penny." The first column gives the name, the second the length in inches, and the third the number per pound:

3-penny,	1 in. long,	557 per lb.
4-penny,	1¼ in. long,	353 per lb.
5-penny,	1¾ in. long,	232 per lb.
6-penny,	2 in. long,	167 per lb.
7-penny,	2¼ in. long,	141 per lb.
8-penny,	2½ in. long,	101 per lb.
10-penny,	2¾ in. long,	98 per lb.
12-penny,	3 in. long,	54 per lb.
20-penny,	3½ in. long,	34 per lb.
Spikes,	4 in. long,	16 per lb.
Spikes,	4½ in. long,	12 per lb.
Spikes,	5 in. long,	10 per lb.
Spikes,	6 in. long,	7 per lb.
Spikes,	7 in. long,	5 per lb.

From this table an estimate of quantity and suitable sizes for any job can be easily made.

The relative adhesion of nails in the same wood, driven transversely and longitudinally, is as 100 to 78, or about 4 to 3 in dry elm, and 2 to 3 in deal.

Horse-power, very Rough Way of Estimating.—The power of a steam engine is calculated by multiplying together the area of the piston in inches, the mean steam pressure in pounds per square inch, the length of stroke in feet, and the number of strokes per minute, and dividing the product by 33,000 Or, multiply the square of the diameter of the cylinder in inches by 0.7854, and this product by the mean engine pressure, and the last product by the piston travel in feet per minute. Divide the last product by 33,000 for the indicated horse-power. In

the absence of logarithmic formulæ or expansion table, multiply the boiler pressure for $\frac{5}{8}$ cut-off by 0.91; for $\frac{1}{2}$ cut-off by 0.85, $\frac{3}{8}$ cut-off by 0.75, $\frac{3}{10}$ cut-off by 0.68. This will give the mean engine pressure per square inch near enough for ordinary practice; for steam pressures between 60 and 100 lbs., always remembering that the piston travel is twice the stroke multiplied by the number of revolutions per minute.

Castings, Contraction of.—By Messrs. Bowen & Co., brass founders, London.

	Inch.	Ins. of length.
In thin brass castings......	$\frac{1}{8}$	in 9
In thick " "	$\frac{1}{8}$	in 10
In zinc castings..............	$\frac{5}{16}$	in 12
In lead, according to purity.	$\frac{3}{16}$ to $\frac{5}{16}$	in 12
In copper " " " .	$\frac{3}{16}$ to $\frac{7}{32}$	in 12
In tin, " " " .	$\frac{1}{32}$ to $\frac{1}{16}$	in 12
In silver, " " " .	$\frac{1}{8}$	in 12
In cast iron, according to purity, small castings....	$\frac{1}{10}$	in 12
In cast steel, according to purity, pipes............	$\frac{1}{8}$	in 12

The above values fluctuate with the form of pattern, amount of ramming, and temperature of metal when poured. Green sand castings contract less than loam or dry sand castings.

Gearing, Simple Rules on.—The following rules will apply to both bevel and spur gears. When the term pitch is used, it always signifies diametrical, not circular pitch. For illustrations we will use gears having 64 teeth and 8 pitch.

To Find Pitch Diameter.—Divide the number of teeth by the pitch: $64 \div 8 = 8$ in. pitch diameter.

To Find Number of Teeth.—Multiply the pitch diameter by the pitch: 8 in.$\times 8 = 64$, number of teeth.

To Find the Pitch.—Divide the number of teeth by the pitch diameter: $64 \div 8$ in.$=8$, pitch.

To Find Outside Diameter of Spur Wheels.—Add 2 to the number of teeth and divide by the pitch. $64 + 2 = 66 \div 8 = 8\frac{1}{4}$ in. O. D.

To Find Circular Pitch.—Divide the decimal 3.1416 by the diametrical pitch: $3.1416 \div 8 = 0.3927$ in.

To Find the Distance between the Centers of Two Spur Gears.—Divide half the sum of the teeth of both gears by the pitch: $64 + 64 = 128 \div 2 = 64 \div 8 = 8$ in. centers.

Pulleys, Rules for Calculating the Speed of.—The diameter of the driven being given, to find its number of revolutions—

Rule.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions of the driven.

Ex.—Twenty-four in. diameter of driver $\times 150$, number of revolutions, $=3{,}600 \div 12$ in. diameter of driven $= 300$.

The diameter and revolutions of the driver being given, to find the diameter of the driven, that shall make any given number of revolutions in the same time.

Rule.—Multiply the diameter of the driver by its number of revolutions, and divide the product by the number of required revolutions of the driven; the quotient will be its diameter.

Ex.—Diameter of driver (as before) 24 in. $\times$revolutions $150 = 3{,}600$. Number of revolutions of driven required $= 300$. Then $3{,}600 \div 300 = 12$ in.

The rules following are but changes of the same, and will be readily understood from the foregoing examples.

To ascertain the size of the driver:

Rule.—Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the required revolutions of the driver; the quotient will be the size of the driver.

To ascertain the size of pulleys for given speed:

Rule.—Multiply all the diameters of the drivers together and all the diameters of the driven together; divide the drivers by the driven; the answer multiply by the known revolutions of main shaft.

Paper, Wall.—The following table from the *New York Newsdealer* shows how many rolls of wall-paper are required to cover a room of the dimensions indicated by the figures in the left-hand column, also the number of yards of border necessary·

Size of Room.	Height of Ceiling.	Number of Doors.	Number of Windows.	Rolls of Paper.	Yards of Border.
7×9	8	1	1	6	11
7×9	9	1	1	7	11
7×9	10	1	1	8	11
7×9	12	1	1	10	11
8×10...........	8	1	1	7	12
8×10...........	9	1	1	8	12
8×10...........	10	1	1	9	12
8×10...........	12	1	1	11	12
9×11...........	8	1	1	8	14
9×11...........	9	1	1	10	14
9×11.	10	1	1	11	14
9×11...........	12	1	1	13	14
10×12...........	8	1	1	9	15
10×12...........	9	1	1	10	15
10×12...........	10	1	1	11	15
10×12	12	1	1	13	15
11×12...........	8	2	2	8	16
11×12...........	9	2	2	9	16
11×12...........	10	2	2	10	16
11×12...........	12	2	2	13	16
12×13...........	8	2	2	8	17
12×13...........	9	2	2	10	17
12×13...........	10	2	2	11	17
12×13...........	12	2	2	14	17
12×15 or 13×14...	8	2	2	10	18
12×15 or 13×14...	9	2	2	11	18
12×15 or 13×14...	10	2	2	12	18
12×15 or 13×14...	12	2	2	15	18
13×15...........	8	2	2	10	19
13×15...........	9	2	2	11	19
13×15...........	10	2	2	13	19
13×15...........	12	2	2	16	19
14×16...........	9	2	2	12	20
14×16...........	10	2	2	14	20
14×16...........	12	2	2	17	20
14×18...........	9	2	2	13	22
14×18...........	10	2	2	15	22
14×18...........	12	2	2	19	22
15×16...........	10	2	2	15	21
15×17...........	12	2	2	19	22

Deduct one-half roll of paper for each ordinary door or window extra—size 4×7 feet.

UNITED STATES STANDARD GAUGE.

For Sheet and Plate Iron and Steel.

Number of Gauge.	Thickness.		Weight.		Number of Gauge.
	Approximate Thickness in Fractions of an Inch.	Approximate Thickness in Decimal Parts of an Inch.	Weight per Square Foot in Ounces Avoirdupois.	Weight per Square Foot in Pounds Avoirdupois.	
0000000	1-2	.5	320	20.	0000000
000000	15-32	.46875	300	18.75	000000
00000	7-16	.4375	280	17.5	00000
0000	13-32	.40625	260	16.25	0000
000	3-8	.375	240	15.	000
00	11-32	.34375	220	13.75	00
0	5-16	.3125	200	12.5	0
1	9-32	.28125	180	11.25	1
2	17-64	.265625	170	10.625	2
3	1-4	.25	160	10.	3
4	15-64	.234375	150	9.375	4
5	7-32	.21875	140	8.75	5
6	13-64	.203125	130	8.125	6
7	3-16	.1875	120	7.5	7
8	11-64	.171875	110	6.875	8
9	5-32	.15625	100	6.25	9
10	9-64	.140625	90	5.625	10
11	1-8	.125	80	5.	11
12	7-64	.109375	70	4.375	12
13	3-32	.09375	60	3.75	13
14	5-64	.078125	50	3.125	14
15	9-128	.0703125	45	2.8125	15
16	1-16	.0625	40	2.5	16
17	9-160	.05625	36	2.25	17
18	1-20	.05	32	2.00	18
19	7-160	.04375	28	1.75	19
20	3-80	.0375	24	1.5	20
21	11-320	.034375	22	1.375	21
22	1-32	.03125	20	1.25	22
23	9-320	.028125	18	1.125	23
24	1-40	.025	16	1.	24
25	7-320	.021875	14	.875	25
26	3-160	.01875	12	.75	26
27	11-640	.0171875	11	.6875	27
28	1-64	.015625	10	.625	28
29	9-640	.0140625	9	.5625	29
30	1-80	.0125	8	.5	30
31	7-640	.0109375	7	.4375	31
32	13-1280	.01015625	6½	.40625	32
33	3-320	.009375	6	.375	33
34	11-1280	.00859375	5½	.34375	34
35	5-640	.0078125	5	.3125	35
36	9-1280	.00703125	4½	.28125	36
37	17-2560	.006640625	4¼	.265625	37
38	1-160	.00625	4	.25	38

ELECTRICAL ENGINEERING.

Units of Measurement.—The three most commonly used units are:

I. The unit of current, called the Ampere;
II. The unit of potential, called the Volt;
III. The unit of resistance, called the Ohm.

For some purposes these quantities are subdivided, thus in telegraphy the practical unit of current is the milli-ampere, *i.e.*, one-thousandth of an ampere. In some cases it is convenient to use multiples; insulation resistances are often expressed in terms of megohms, *i.e.*, a million ohms. The most commonly used multiples are the following:

1 Megohm $= 10^6$ ohms $= 1$ million ohms,
1 Microhm $= 10^{-6}$ ohm $= 1$ millionth of an ohm,
1 Kilowatt $= 10^3$ watts $= 1{,}000$ watts,
1 Micro-ampere $= 10^{-6}$ ampere $= 1$ millionth of an ampere.

Ohm's Law.—For steady currents the three quantities—current, potential and resistance—are connected together by the relation discovered by Dr. Ohm, and called Ohm's Law. This law is stated thus

$$C = \frac{E}{R};$$

where C = current (amperes);
E = difference of potential (volts);
R = resistance opposing the current (ohms).

All the units in scientific work are defined in terms of the fundamental units, which are

Unit of length = 1 centimeter.
" " mass = 1 gram.
" " time = 1 second.

These are spoken of as the C.G.S. units, and in the actual determination of a standard

ohm attempts have been made to obtain the scientific value as closely as possible. The first unit used as a standard was the British Association or B.A. unit coil. Messrs. Siemens also introduced a standard ohm, but both of these units differed from the true ohm as well as from each other. In order to avoid the consequent confusion, an international congress was held at Paris in 1893 to decide upon the standard values to be adopted.

C. G. S. ELECTRICAL STANDARDS.

THE OHM is represented by the resistance offered by a column of mercury—at the temperature of melting ice—14.4521 grams in mass, of a constant cross-sectional area, and of a length of 106.3 centimeters.

THE AMPERE is represented by the unvarying electric current which, when passed through a solution of nitrate of silver in water, deposits silver at the rate of 0.001118 of a gram per second.

THE VOLT is the electrical pressure which, if steadily applied to a conductor whose resistance is 1 ohm, will produce a current of 1 ampere, and which is represented by 0.6974, or $\frac{1000}{1434}$ of the electrical pressure between the poles of the voltaic cell, known as Clark's cell, at a temperature of 15° C. (59° F.).

As in many of the older books and early papers dealing with electrical matters the older system of units is used, the following table will be useful for ascertaining the relative values of the quantities expressed:

System.	True Ohm.	Legal Ohm.	B.A. Ohm.	Siemens Ohm.
True Ohm.	1.0000	1.0025	1.0138	1.0630
Legal Ohm. . . .	0.9975	1.0000	1.0113	1.0600
B.A. Ohm. . . .	0.9863	0.9889	1.0000	1.0482
Siemens Ohm. .	0.9408	0.9434	0.9540	1.0000

UNIT OF QUANTITY.—The quantity of electricity that flows per second past a cross-section of a conductor carrying a current of one ampere is a Coulomb.

The practical unit is the quantity that flows per hour, and is measured in ampere-hours.

UNIT OF CAPACITY: THE FARAD.—The capacity of two conductors insulated from each other is the number of coulombs of electricity required to be given to one conductor, the other being supposed at zero potential, to produce a difference of pressure of 1 volt between the two. The unit of capacity is called a "farad," and two conductors arranged in a form known as a condenser of 1 farad capacity would be raised to a difference of pressure of 1 volt by a charge of 1 coulomb of electricity. The practical unit used, however, has a capacity one-millionth of a farad—*i.e.*, a microfarad.

JOULE.—When a power of one *watt* is being developed, the work done per second is sometimes called a "Joule." Hence, *one joule* equals 0.7375 foot-lb., and

1 watt-second = 1 joule.
1 watt-minute = 60 joules.
1 horse-power hour = 1,980,000 foot-lbs.
1 horse-power hour = 2,685,600 joules.
(*W. E. Ayrton.*)

WATT.—A "watt" is the power developed in a circuit when one ampere flows through it, and when the potential difference at its terminals is one volt; hence the number of watts developed in any circuit equals the product of the current in amperes flowing through it into the potential difference at its terminals in volts. Therefore

1 watt is the power developed when 44.25 foot-lbs. of work are done per minute.

1 watt is the power developed when 0.7375 foot-lb. of work is done per second.

1 watt equals $\frac{1}{746}$th of a horse-power.
(*W. E. Ayrton.*)

CALORIE.—The amount of heat required to raise 1 kilogram of water 1° C. is the unit of heat employed on the Continent.

1 calorie = 4,200 joules = 42×10^9 ergs.
1 joule = 0.000238 calories.

INDUCTION: THE HENRY.—The induction in a circuit when the difference of electrical pressure induced in the circuit is 1 volt, while the inducing current varies at the rate of 1 ampere per second, is called a "Henry."

THE ELECTRO-MAGNETIC SYSTEM OF ELECTRIC UNITS.

UNIT OF CURRENT.—That current which, flowing in a conductor 1 centimeter long, and of 1 centimeter radius, produces at the center of the arc a magnetic field of unit strength.

This unit is ten times the ampere.

UNIT OF POTENTIAL.—Unit difference of potential exists between the ends of a conductor, when the expenditure of 1 erg per second will cause unit current to flow.

This E.M.F. is equal to one hundred-millionth of a volt.

Note.—The erg = work done by a force of 1 dyne through a distance of one centimeter = 0.001019 gramme—cent = 0.00000007386 foot-lb. (London).

UNIT OF RESISTANCE is that resistance which requires unit difference of potential to cause unit current to flow.

This resistance is 1,000-millionth of an ohm.

For ready reference the units most frequently used in practice are tabulated below, together with their value in C.G.S. absolute units.

Electrical Quantity.	Name of Unit.	Dimensions of Unit.	Value in C.G.S. Units.
Resistance.	Ohm.	LT^{-1}	10^9 C.G.S. units.
Current.	Ampere.	$L^{\frac{1}{2}}M^{\frac{1}{2}}T^{-1}$	10^{-1} " "
Electrical pressure.	Volt.	$L^{\frac{3}{2}}M^{\frac{1}{2}}T^{-2}$	10^8 " "
Energy.	Joule.	L^2MT^{-2}	10^7 " "
Capacity.	Farad	$L^{-1}T^2$	10^{-9} " "
Capacity.	Microfarad	. . . .	10^{-15} " "
Power.	Watt.	L^2MT^{-3}	10^7 " "
Power.	Kilowatt.	. . . .	10^{10} " "
Work.	Watt-hour.	. . . .	$10^9 \times 36$ "
Work.	Kilowatt-hour. . . .	. . . .	$10^{12} \times 36$ "

UNITS OF FORCE, PRESSURE, WORK, POWER.

FORCE.—1 *dyne* = that force which acting on 1 gramme for 1 second gives it a velocity of 1 centimeter per second (being absolute unit of force in the C.G.S. system, independent of local variations of gravity).

1 *gram weight* = at Paris, 980 dynes; at London, 981 dynes; at Glasgow, 982 dynes.

1 *pound weight* = 453.6 grams weight; = at Paris, 444,528 dynes; at London, 444,987 dynes.

PRESSURE.—1 *pound per square inch* = 0.0703 kilogram per square centimeter.

1 *kilogram per square centimeter* = 14.2 lbs. per square inch.

1 *atmosphere* = 30 in. of mercury = nearly 76 centimeters of mercury = nearly 15 lbs. per square inch = nearly 1,000,000 dynes per square centimeter.

The following will serve to illustrate the magnitude of some of these units:

10 ft. of pure copper wire 0.01 in. diameter is almost exactly equal to 1 ohm.

The current used in an ordinary incandescent lamp of 16 candle-power is about 0.6 ampere.

The electrical pressure of the terminals of the cell usually used for electric bells (Leclanche) is about 1.4 volt.

1 watt = about 44¼ foot-lbs. per minute.
746 watts = 1 horse-power
1 kilowatt = about 1⅓ horse-power.

An easy way to convert watts into the equivalent horse-power is to mark off three places and add one-third: Thus,

What is the equivalent horse-power of 27,000 watts?

Set off three decimal places........	27.000
Add one-third....................	9.000
And the horse-power required =	36

Find the equivalent number of watts of 48 electrical horse-power?

Multiply the horse-power by 1,000, thus 48 × 1,000	= 48,000
Subtract one-quarter, $\frac{48000}{4}$	= 12,000
And the required number of watts	= 36,000

RESISTANCE.

CONDUCTORS.—Nearly all substances as they occur in nature conduct electricity—*i.e.*, if the substance is joined to a source of electrical energy, a magnetic field is created around it. Roughly, three groups of conductors may be formed, but of very varying degree: 1st, good conductors, pure metals, and alloys of metals; 2d, at a long interval, solutions of electrolytes—*i.e.*, solutions capable of being decomposed by the passage of an electric current through them; and 3d, very bad conductors, such as India rubber, ebonite, shellac, sulphur, glass, slate, marble, stoneware, mica, dry wood and paper, animal fibers (silk, wool, furs), petroleum oil, paraffin wax, ozokerit, pitch, bitumen, etc. Usually, in practical work, the first class is spoken of as conductors, and the third class as insulators.

RESISTANCE.—The resistance of a conductor is

(*a*) Directly proportional to its length; (*b*) Inversely proportional to its cross-sectional area; (*c*) Directly proportional to its specific resistance; (*d*) and usually increases with its temperature.

SPECIFIC RESISTANCE.—The specific resistance of a substance is usually stated as the resistance between the faces of a cube of the substance, 1 centimeter in length and 1 square centimeter in cross-sectional area.

The law of resistance may be stated thus, neglecting the effect of temperature:

$$R = \frac{\rho l}{s};$$

where
R = the resistance in ohms;
l = the length of conductor;
s = the cross-sectional area of the conductor;
ρ = the specific resistance of the material.

RESISTANCE OF METALS AND ALLOYS (CHEMICALLY PURE) AT 32° F. IN STANDARD OHMS.

Metal.	(ρ) Specific Resistance Cubic Centimeter. Microhms.	Resistance per Foot, $\frac{1}{1000}$ Inch Diameter.	Resistance per Meter, 1 Millimeter Diameter.	Relative Resistance.
		Ohms.	Ohms.	
Silver, annealed....	1.5006	9.0283	0.01911	1.000
" hard-drawn....	1.6298	9.8028	0.02074	1.086
Copper, annealed....	1.61966	10.2063	0.02160	1.130
" hard-drawn....	1.73054	10.4117	0.02204	1.153
Gold, annealed....	2.0531	12.3522	0.02614	1.369
" hard-drawn....	2.0896	12.5692	0.0266	1.393
Aluminum, annealed....	2.9055	17.4825	0.037	1.935
Zinc, pressed....	5.6127	33.7614	0.071	3.741
Platinum, annealed....	9.0352	54.3517	0.115	6.022
Iron, annealed....	9.6933	58.308	0.123	6.460
Lead, pressed....	19.584	117.79	0.249	13.05
German silver, hard or annealed....	20.886	125.62	0.266	13.92
Platinum, silver alloy (2 parts silver and 1 part platinum), hard or annealed....	24.329	146.36	0.310	16.21
Manganese steel....	75	447.50	0.95	49.7
Mercury....	96	570.84	1.208	62.73

APPROXIMATE PERCENTAGE VARIATION IN RESISTANCE AT ABOUT 20° C. (68° F.)

Metal or Alloy.	(a) Per 1° C.	(a) Per 1° F.
Platinum Silver (1 pt. Platinum to 2 pts. Silver), hard or annealed	0.031	0.017
German Silver, hard or annealed	0.044	0.024
Mercury	0.072	0.040
Bismuth, pressed	0.354	0.197
Gold, annealed	0.365	0.203
Zinc, pressed	0.365	0.203
Tin, "	0.365	0.203
Silver, annealed	0.377	0.209
Lead, pressed	0.387	0.215
Copper, annealed	0.428	0.238
Iron (about)	0.5	0.278

—*Practical Engineer's Electrical Pocket-Book and Diary.*

HEAT AND ELECTRICAL CONDUCTIVITY.

Substances.	Heat Conductivity.	Electrical Conductivity.
Silver	100.0	100.0
Copper	73.6	73.3
Gold	53.2	58.5
Brass	23.6	21.5
Zinc	19.9	....
Tin	14.5	22.6
Steel	12.0	....
Iron	11.9	13.0
Lead	8.5	10.7
Platinum	6.4	10.3
Palladium	6.3	....
Bismuth	1.8	1.9

RESISTANCE AND WEIGHT TABLE.

American gauge for cotton and silk-covered and bare copper wire.—The resistances are calculated for pure copper wire.

The number of feet to the pound is only approximate for insulated wire.

No.	Diameter.	Feet per Pound.			Resistance, Naked Copper.			
		Cotton Covered.	Silk Covered.	Naked.	Ohms per 1,000 Feet.	Ohms per Mile.	Feet per Ohm.	Ohms per Pound.
8	.12849	....	....	20	.6259	3.3	1600	.0125
9	.11443	....	....	25	.7892	4.1	1272	.0197
10	.10189	....	....	32	.8441	4.4	1185	.0270
11	.09074	....	....	40	1.254	6.4	798	.0501
12	.08081	42	46	50	1.580	8.3	633	.079
13	.07196	55	60	64	1.995	10.4	504	.127
14	.06408	68	75	80	2.504	13.2	400	.200
15	.05707	87	95	101	3.172	16.7	316	.320
16	.05082	110	120	128	4.001	23	230	.512
17	.04525	140	150	161	5.04	26	198	.811
18	.0403	175	190	203	6.36	33	157	1.29
19	.03539	220	240	256	8.25	43	121	2.11
20	.03196	280	305	324	10.12	53	99	3.27
21	.02846	360	390	408	12.76	68	76.5	5.20
22	.02535	450	490	514	16.25	85	61.8	8.35
23	.02257	560	615	649	20.30	108	48.9	13.3
24	.0201	715	775	818	25.60	135	39.0	20.9
25	.0179	910	990	1,030	32.2	170	31.0	33.2
26	.01594	1,165	1,265	1,300	40.7	214	24.6	52.9
27	.01419	1,445	1,570	1,640	51.3	270	19.5	84.2
28	.01264	1,810	1,970	2,070	64.8	343	15.4	134
29	.01126	2,280	2,480	2,617	81.6	432	12.2	213
30	.01002	2,805	3,050	3,287	103	538	9.8	338
31	.00893	3,605	3,920	4,144	130	685	7.7	539
32	.00795	4,535	4,930	5,227	164	865	6.1	856
33	.00708	....	6,200	6,590	206	1033	4.9	1357
34	.0063	....	7,830	8,330	260	1389	3.8	2166
35	.00561	....	9,830	10,460	328	1820	2.9	3521
36	.005	....	12,420	13,210	414	2200	2.4	5409

WEIGHT IN POUNDS PER MILE OF COPPER WIRE.

Number.	Roebling.	Birmingham.	Brown & Sharpe.	English Legal Standard.	Number.	Roebling.	Birmingham.	Brown & Sharpe.	English Legal Standard.
0000	2,466	3,286	3,375	2,555	14	102	110	65	102
000	2,092	2,884	2,677	2,210	15	83	83	52	83
00	1,750	2,305	2,123	1,933	16	64	68	41	65
0	1,504	1,846	1,684	1,682	17	47	53¾	33	50
1	1,278	1,437	1,335	1,437	18	35	38	26	37
2	1,104	1,287	1,058	1,216	19	27	28	20¾	26
3	950	1,071	839	1,012	20	19½	19½	16¼	20¾
4	808	904	665	860	21	16⅓	16¼	13	16¼
5	684	773	528	718	22	12½	12½	10¼	12½
6	588	657	418	588	23	10¼	10¼	8⅛	9¼
7	500	517	332	495	24	8¼	7¾	6½	7¾
8	419	435	263	409	25	6½	6½	5⅛	6½
9	350	350	209	332	26	5	5	4	5
10	291	287	166	263	27	4½	4	3¼	4
11	230	230	131	215	28	4	3¼	2½	3½
12	176	190	104	173	29	3⅝	2⅝	2	3
13	135	144	83	135	30	3¼	2¼	1⅝	2½

WIRE GAUGES, IN DECIMAL PARTS OF AN INCH.

Number of Wire Gauge.	Roebling.	Brown & Sharpe.	Birmingham or Stubs.	English Legal Standard.	Old English, or London.
000000	0.46	......	......	0.464	......
00000	0.43	......	......	0.432	......
0000	0.393	0.46	0.454	0.4	0.454
000	0.362	0.40964	0.425	0.372	0.425
00	0.331	0.3648	0.380	0.348	0.38
0	0.307	0.32495	0.340	0.324	0.34
1	0.283	0.2893	0.3	0.3	0.3
2	0.263	0.25763	0.284	0.276	0.284
3	0.244	0.22942	0.259	0.252	0.259
4	0.225	0.20431	0.238	0.232	0.238
5	0.207	0.18194	0.22	0.212	0.22
6	0.192	0.16202	0.203	0.192	0.203
7	0.177	0.14428	0.18	0.176	0.18
8	0.162	0.12849	0.165	0.16	0.165
9	0.148	0.11443	0.148	0.144	.148
10	0.135	0.10189	0.134	0.128	0.134
11	0.12	0.09074	0.12	0.116	0.12
12	0.105	0.08081	0.109	0.104	0.109
13	0.092	0.07196	0.095	0.092	0.095
14	0.08	0.06408	0.083	0.08	0.083
15	0.072	0.05706	0.072	0.072	0.072
16	0.063	0.05082	0.065	0.064	0.065
17	0.054	0.04525	0.058	0.056	0.058
18	0.047	0.0403	0.049	0.048	0.049
19	0.041	0.03589	0.042	0.04	0.04
20	0.035	0.03196	0.035	0.036	0.035
21	0.032	0.02846	0.032	0.032	0.0315
22	0.028	0.02534	0.028	0.028	0.0295
23	0.025	0.02257	0.025	0.024	0.027
24	0.023	0.0201	0.022	0.022	0.025
25	0.02	0.0179	0.02	0.02	0.023
26	0.018	0.01594	0.018	0.018	0.0205
27	0.017	0.01419	0.016	0.0164	0.01875
28	0.016	0.01264	0.014	0.0148	0.0165
29	0.015	0.01125	0.013	0.0136	0.0155
30	0.014	0.01002	0.012	0.0124	0.01375
31	0.0135	0.00893	0.010	0.0116	0.01225
32	0.013	0.00795	0.009	0.0108	0.01125
33	0.011	0.00708	0.008	0.01	0.01025
34	0.01	0.0063	0.007	0.0092	0.0095
35	0.0095	0.00561	0.005	0.0084	0.009
36	0.009	0.005	0.004	0.0076	0.0075

TABLE INDICATING SIZE, WEIGHT, AND LENGTH OF IRON AND STEEL WIRE.

Gauge Numbers.	Diameter, Ins.	W'ight of 100 Feet. Lbs.	W'ight of One Mile, Lbs.	Feet in 2000 Lbs.	Area. Square Ins
3–0	.362	34.73	1834	5,759	.102921
2–0	.331	29.04	1533	6,886	.086049
1–0	.307	25.00	1318	8,000	.074023
1	.283	21.23	1121	9,425	.062901
2	.263	18.34	968	10,905	.054325
3	.244	15.78	833	12,674	.046759
4	.225	13.39	707	14,936	.039760
5	.207	11.35	599	17,621	.033653
6	.192	9.73	514	20,555	.028952
7	.177	8.30	439	24,906	024605
8	.162	6.96	367	28,734	.020612
9	.148	5.80	306	34,483	.017203
10	.135	4.83	255	41,408	.014313
11	.120	3.82	202	52,356	.011309
12	.105	2.92	154	68,493	.008659
13	.092	2.24	118	89,286	.006647
14	.080	1.69	89	118,343	.005026
15	.072	1.37	72	145,985	.004071
16	.063	1.05	55	190,476	.003117
17	.054	0.77	41	259,740	.002290
18	.047	0.58	31	344,827	.001734
19	.041	0.45	24	444,444	.001320
20	.035	0.32	17	625,000	.000962
21	.032	0.27	14	740,741	.000804
22	.028	0.21	11	952,381	.000615
23	.025	0.175	9.24	......	.000491
24	.023	0.140	7.39	......	.000415
25	.020	0.116	6.124	......	.000314
26	.018	0.093	4.91	......	.000254
27	.017	0.083	4.382	......	.000227
28	.016	0.074	3.907	......	.000201
29	.015	0.061	3.22	......	.000176
30	.014	0.054	2.851	......	.000154
31	.0135	0.050	2.64	......	.000143
32	.013	0.046	2.428	......	.000132
33	.011	0.037	1.953	......	.000095
34	.010	0.030	1.584	......	.000078
35	.0095	0.025	1.32	......	.000071
36	.009	0.021	1.161	......	.000064

ELECTRICAL HORSE-POWER.

Calculated from $\frac{E \times C}{746}$.

Current in Amperes.	E.M.F. in Volts.														
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
5	0.06	0.13	0.20	0.28	0.33	0.40	0.47	0.53	0.60	0.67	0.73	0.80	0.87	0.93	1.0
10	0.13	0.28	0.40	0.53	0.67	0.80	0.93	1.07	1.2	1.3	1.4	1.6	1.6	1.9	2.0
20	0.28	0.53	0.80	1.07	1.3	1.6	1.9	2.1	2.4	2.7	2.9	3.2	3.5	3.7	4.0
30	0.40	0.80	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0
40	0.53	1.07	1.6	2.1	2.6	3.2	3.7	4.2	4.8	5.3	5.9	6.4	6.9	7.5	8.0
50	0.67	1.30	2.0	2.6	3.3	4.0	4.6	5.4	6.0	6.7	7.4	8.0	8.7	9.4	10.0
60	0.80	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	8.8	9.6	10.4	11.2	12.0
70	0.93	1.9	2.8	3.7	4.6	5.6	6.5	7.5	8.4	9.4	10.3	11.2	12.3	13.1	14.0
80	1.07	2.1	3.2	4.2	5.4	6.4	7.5	8.5	9.6	10.7	11.8	12.8	13.9	15.0	16.0
90	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4	15.6	16.9	18.0
100	1.3	2.7	4.0	5.3	6.7	8.0	9.4	10.7	12.0	13.4	14.7	16.0	17.4	18.7	20.0
110	1.4	2.9	4.4	5.9	7.4	8.8	10.3	11.8	13.2	14.7	16.2	17.6	19.1	20.6	22.0
120	1.5	3.2	4.8	6.4	8.0	9.6	11.2	12.8	14.4	16.0	17.6	19.2	20.9	22.5	24.0
130	1.6	3.5	5.2	6.9	8.7	10.4	12.3	13.9	15.6	17.4	19.1	20.9	22.6	24.4	26.0
140	1.9	3.7	5.6	7.5	9.4	11.2	13.1	15.0	16.9	18.7	20.6	22.5	24.4	26.2	28.0
150	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0

E.H.P. on current line, under E.M.F.

COMPOSITION AND ELECTROMOTIVE FORCE OF BATTERY CELLS.

Name.	Electrodes.	Solutions.	E.M.F.
Clark.	Pure mercury and pure zinc.	The mercury is covered with a paste of mercurous sulphate and a saturated solution of zinc sulphate, in which is placed the rod of zinc.	1.434 at 15° C. at any temp t° C. it is $1.434[1 - .0008(t° - 15°)]$.
Daniell.	Copper and zinc.	The zinc is immersed in a solution of zinc sulphate, and the copper in a solution of copper sulphate.	Depends upon the densities of the solutions; it varies from 1.07 to 1.14 volts.
Groves.	Platinum and zinc.	The platinum is immersed in a strong nitric acid, and the zinc in dilute sulphuric acid.	About 1.93 volts.
Bunsen.	Carbon and zinc.	The carbon in nitric acid, and the zinc in dilute sulphuric acid.	About 1.74 volts.
Leclanche.	Carbon and zinc.	The carbon is packed in a porous pot with peroxide of manganese and broken gas carbon. The zinc is immersed in solution of sal ammoniac.	About 1.47 volts; but is quickly reduced if used to send a strong current.
Potash-bichromate.	Carbon and zinc.	The best solution is 1 lb. of potassium-bichromate, 2 lbs. strong sulphuric acid sp. gr. 1.836, and 12 lbs. water, in which both electrodes are immersed, the zinc being withdrawn when the cell is not in use.	About 2 volts; but is quickly reduced if employed to send a strong current.

—Practical Engineers' Electrical Pocket Book.

THE AMOUNT OF ONE DOLLAR AT COMPOUND INTEREST.

End of Year.	3 Per Cent.	3½ Per Cent.	4 Per Cent.	4½ Per Cent.	5 Per Cent.	6 Per Cent.	7 Per Cent.
1	$1.03	$1.04	$1.04	$1.05	$1.05	$1.06	$1.07
2	1.06	1.07	1.08	1.09	1.10	1.12	1.14
3	1.09	1.11	1.12	1.14	1.16	1.19	1.23
4	1.13	1.15	1.17	1.19	1.22	1.26	1.31
5	1.16	1.19	1.22	1.25	1.28	1.34	1.40
6	1.19	1.23	1.27	1.30	1.34	1.42	1.50
7	1.23	1.27	1.32	1.36	1.41	1.50	1.61
8	1.27	1.32	1.37	1.42	1.48	1.59	1.72
9	1.30	1.36	1.42	1.49	1.55	1.69	1.84
10	1.34	1.41	1.48	1.55	1.63	1.79	1.97
11	1.38	1.46	1.54	1.62	1.71	1.90	2.10
12	1.43	1.51	1.60	1.70	1.80	2.01	2.25
13	1.47	1.56	1.67	1.77	1.89	2.13	2.41
14	1.51	1.62	1.73	1.85	1.98	2.26	2.58
15	1.56	1.68	1.80	1.94	2.08	2.40	2.76
16	1.60	1.73	1.87	2.02	2.18	2.54	2.95
17	1.65	1.79	1.95	2.11	2.29	2.69	3.16
18	1.70	1.86	2.03	2.21	2.41	2.85	3.38
19	1.75	1.92	2.11	2.31	2.53	3.03	3.62
20	1.81	1.99	2.19	2.41	2.65	3.21	3.87
21	1.86	2.06	2.28	2.52	2.79	3.40	4.14
22	1.92	2.13	2.37	2.63	2.93	3.60	4.43
23	1.97	2.21	2.46	2.75	3.07	3.82	4.74
24	2.03	2.28	2.56	2.88	3.23	4.05	5.07
25	2.09	2.36	2.67	3.01	3.39	4.29	5.43
26	2.16	2.45	2.77	3.14	3.56	4.55	5.81
27	2.22	2.53	2.88	3.28	3.73	4.82	6.21
28	2.29	2.62	3.00	3.43	3.92	5.11	6.65
29	2.36	2.71	3.12	3.58	4.12	5.42	7.11
30	2.43	2.81	3.24	3.75	4.32	5.74	7.61
31	2.50	2.91	3.37	3.91	4.54	6.09	8.15
32	2.58	3.01	3.51	4.09	4.76	6.45	8.72
33	2.65	3.11	3.65	4.27	5.00	6.84	9.33
34	2.73	3.22	3.79	4.47	5.25	7.25	9.98
35	2.81	3.33	3.95	4.67	5.52	7.69	10.68
36	2.90	3.45	4.10	4.88	5.79	8.15	11.42
37	2.99	3.57	4.27	5.10	6.08	8.64	12.22
38	3.07	3.70	4.44	5.33	6.39	9.15	13.08
39	3.17	3.83	4.62	5.57	6.70	9.70	13.99
40	3.26	3.96	4.80	5.82	7.04	10.29	14.97
41	3.36	4.10	4.99	6.08	7.39	10.90	16.02
42	3.46	4.24	5.19	6.35	7.76	11.56	17.14
43	3.56	4.39	5.40	6.64	8.15	12.25	18.34
44	3.67	4.54	5.62	6.94	8.56	12.99	19.63
45	3.78	4.70	5.84	7.25	8.99	13.76	21.00
46	3.90	4.87	6.07	7.57	9.43	14.59	22.47
47	4.01	5.04	6.32	7.92	9.91	15.47	24.05
48	4.13	5.21	6.57	8.27	10.40	16.39	25.73
49	4.26	5.40	6.83	8.64	10.92	17.38	27.53
50	4.38	5.58	7.11	9.03	11.47	18.42	29.46

ROMAN NOTATION.

1 = I.
2 = II.
3 = III.
4 = IV.
5 = V.
6 = VI.
7 = VII.
8 = VIII.
9 = IX.
10 = X.
20 = XX.
30 = XXX.
40 = XL.
50 = L.
60 = LX.
70 = LXX.
80 = LXXX.

90 = XC.
100 = C
500 = D, or LↃ.
1,000 = M, or CↃ.
2,000 = MM, or IIↃↃↃ.
5,000 = V, or LↃↃ.
6,000 = VI, or MMM.
10,000 = $\overline{\text{X}}$, or CↃↃ.
50,000 = $\overline{\text{L}}$, or LↃↃↃ.
60,000 = $\overline{\text{LX}}$, or MMMↃ.
100,000 = $\overline{\text{C}}$, or CↃↃↃ.
1,000,000 = $\overline{\text{M}}$, or CↃↃↃↃ.
2,000,000 = $\overline{\text{MM}}$, or MMↃↃↃ.

A line over a number increases it 1,000 times.

STANDARD TABLE OF HEIGHT AND WEIGHT.

Height.	Weight.		
	Maximum.	Standard.	Minimum.
4 feet 10 inches	150	105	83
4 " 11 "	160	110	87
5 "	167	115	92
5 " 1 "	174	120	96
5 " 2 "	181	125	100
5 " 3 "	188	130	104
5 " 4 "	195	135	108
5 " 5 "	200	140	112
5 " 6 "	205	145	115
5 " 7 "	210	150	120
5 " 8 "	215	155	125
5 " 9 "	220	160	130
5 " 10 "	225	165	135
5 " 11 "	230	170	140
6 "	235	175	145
6 " 1 "	240	180	150
6 " 2 "	245	185	155
6 " 3 "	250	190	160
6 " 4 "	255	195	165

—Table furnished by F. L. Hoffman, Insurance Statistician.

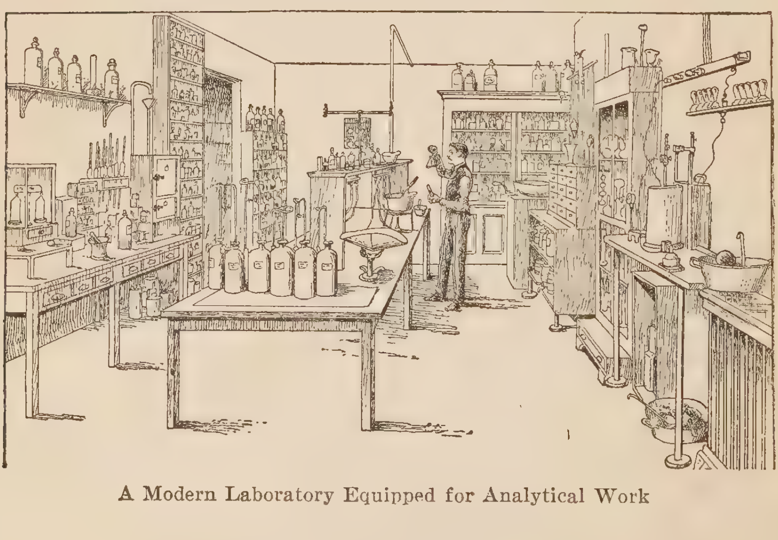
THE AMERICAN EXPERIENCE TABLE OF MORTALITY.

Age.	Expectation of Life in Years.	Number Dying in Each 1,000.	Age.	Expectation of Life in Years.	Number Dying in Each 1,000.
20	42.20	7.81	60	14.10	26.69
21	41.53	7.86	61	13.47	28.88
22	40.85	7.91	62	12.86	31.29
23	40.17	7.96	63	12.26	33.94
24	39.49	8.01	64	11.67	36.87
25	38.81	8.07	65	11.10	40.13
26	38.12	8.13	66	10.54	43.71
27	37.43	8.20	67	10.00	47.65
28	36.73	8.26	68	9.47	52.00
29	36.03	8.35	69	8.97	56.76
30	35.33	8.43	70	8.48	61.99
31	34.63	8.51	71	8.00	67.67
32	33.92	8.61	72	7.55	73.73
33	33.21	8.72	73	7.11	80.18
34	32.50	8.83	74	6.68	87.03
35	31.78	8.95	75	6.27	94.37
36	31.07	9.09	76	5.88	102.31
37	30.35	9.23	77	5.49	111.06
38	29.62	9.41	78	5.11	120.83
39	28.90	9.59	79	4.74	131.73
40	28.18	9.79	80	4.39	144 47
41	27.45	10.01	81	4.05	158.61
42	26.72	10.25	82	3.71	174.30
43	26.00	10.52	83	3.39	191.56
44	25.27	10.83	84	3.08	211.36
45	24.54	11.16	85	2.77	235.55
46	23.81	11.56	86	2.47	265.68
47	23.08	12.00	87	2.18	303.02
48	22.36	12.51	88	1.91	346.69
49	21.63	13.11	89	1.66	395.86
50	20.91	13.78	90	1.42	454.55
51	20.20	14.54	91	1.19	532.47
52	19.49	15.39	92	.98	634.26
53	18.79	16.33	93	.80	734.18
54	18.09	17.40	94	.64	857.14
55	17.40	18.57	95	.50	1000.00
56	16.72	19.89			
57	16.05	21.34			
58	15.39	22.94			
59	14.74	24.72			

PART II.

Chemical Manipulation

Chemical Operations are Best Carried on With Proper Equipment



A Modern Laboratory Equipped for Analytical Work

CHEMICAL MANIPULATIONS

The proper preparation and manipulation of chemical and other substances is of paramount importance and much of the non-success of amateurs may be laid to this lack of knowledge. Much of the apparatus required can be constructed at home, but glassware of convenient shapes should be purchased from dealers in chemical apparatus. It will pay in the long run to have good supplies from reliable houses. A fairly good little laboratory for making various articles given in the formulas would cost from $50.00 to $100.00. Of course, where the manufacture of an article is to be carried on commercially a special plant is needed, much of which can be supplied by the chemical supply houses noted above. A request to the publishers of this book will bring a list of dealers in such lines. Addresses must necessarily be excluded in a work of reference which is of permanent value. A catalogue of chemicals should be at the right hand of all experimenters. The number of rare things hard to get at the ordinary drug store which they carry is very considerable, such as agar agar, alizarin, aloes, amber, aniline colors, animal charcoal, aqua regia, asbestos, Canada balsam, banana oil, barium, Brunswick black, Burgundy pitch, etc., to only enumerate a few titles out of the first two letters of the alphabet. The prices of a few are noted a little further on. So far as possible always strive to deal with these chemical houses, as this will insure good materials, without which no success is possible. Until you wish to make an article on a commercial scale always buy the most expensive and best materials; after success has been obtained it is fairly safe to use cheaper materials if the skill which has been attained is sufficient to make a superior product with more economical raw materials.

The entire subject of manipulation has been divided as follows:

LABORATORY OPERATIONS

I
COMMINUTION

SLICING
RASPING
CONTUSION
GRINDING
PULVERIZING
TRITURATION
PORPHYRIZATION
SIFTING
LEVIGATION
GRANULATION
ELUTRIATION
PULVERIZATION BY INTERVENTION

II
SOLUTION AND EXTRACTION

EXPRESSION
MACERATION
DECOCTION
INFUSION
DIGESTION
DESSICATION

III
VAPORIZATION

EVAPORATION
DISTILLATION

IV
PRECIPITATION AND SEPARATION

PRECIPITATION
STRAINING
CLARIFICATION
CENTRIFUGATION
WASHING
DECANTATION
PERCOLATION
FILTRATION
PRECIPITATION
CRYSTALLIZATION.
GRANULATION
DIALYSIS
DECOLORIZATION
EMULSIFICATION

V

HEAT TREATMENT OF SOLIDS

IGNITION
FUSION
CALCINATION
ROASTING
DEFLAGRATION
DECREPITATION
CARBONIZATION
REDUCTION
TORREFACTION
INCINERATION
SUBLIMATION

VI

SPECIFIC GRAVITY

The following list, which numbers about 800 substances, is intended to answer the myriad of questions of price which have been so often asked the editor. The list does not take in either the ordinary or extraordinary chemicals of commerce, either medical or technical, more or less complete lists of which can be consulted at any druggist's, but the list does take up the flotsam and jetsam of technology, and it is thought that it would be handy to have prices on articles such as agar agar, aniline colors, essences, bay leaves, fluorspar, fusible metal, nickel anodes, oyster shells, pipe clay, mineral wool. Every user of this book is earnestly requested to obtain a full list of drugs and chemicals issued by any one of four or five prominent dealers in chemicals. The lists include many thousand articles and they are so valuable that the catalogues of all the dealers should be bound together for reference. Most dealers expect 5 or 10 cents for postage on their catalogues. It should, of course, be remembered that fluctuations in the price of articles listed are apt to be quite considerable, yet no one will be seriously misled if catalogues of dealers are kept on file as suggested. These fluctuations will hardly take away from the value of the list. The list was compiled from five catalogues and contains perhaps a wider range of subjects than can be found in any one of them. Of course a list of acids in any one of them, for instance, is very extensive, as is also all of, say, the sodium preparations, which may easily number over 150 different chemicals and states of purity. The same might be said of almost any important chemical.

It should be noted that all bottles, cans, and in fact all containers, are charged for, as well as packing cases if any are required. The postal laws exclude from the mail poisons, glass, explosives, spontaneously combustible chemicals or any other matter liable to injure or deface the contents of the mail. Strong acids, phosphorus, potassium, sodium or other articles considered dangerous by the carriers on account either of inflammability or liability to cause injury to other freight are refused conveyance by the express companies, but can be shipped by freight lines.

	Per oz.	Per lb.
Agar agar	$0.10	$0.75
Threads	..	.85
Powder	.20	1.85
Sticks	.10	1.00
Albolene:		
Solid	..	.40
Liquid	..	.40
Albumen:		
From eggs	.10	.90
From blood	.10	.35
Alizarin:		
Paste, 20%	.10	.60
Assistant (Turkey red oil)	.10	.50
Alkanet root	..	.25
Almonds:		
Bitter	..	.37
Sweet	..	.35
Jordan	..	.35
Flour	..	.40
Aloes, Socotrine	.10	.40
Alum, burnt or calcined	..	.15
Aluminum:		
Bars	..	.75
Foil	.20	..
Sheet	..	1.50
Wire	.20	..
250-leaf book—$1.25.		
Leaf bronze	..	1.15
Amalgam:		
Electric	.12	.75
Copper	.25	2.85
Of sodium	.20	1.50
Tin-zinc	.30	4.80
Zinc	..	.60
Amber:		
Crude	.06	.50
Clear	..	1.25
Ambergris, black, $3.50 dram; gray, $4.50 dram.		
Amyl acetate	..	.80
Aniline oil	.05	.30
Aniline C. P.	.10	1.00

	Per oz.	Per lb.
Aniline Colors:		
Black, soluble in water (Nigrosine)	.20	1.25
Blue, soluble in water	.15	1.50
Blue, red shade	.15	1.75
Blue, gentian	.40	..
Blue, Lyons	.25	..
Blue, methyl	.20	1.75
Blue, methylene	.35	..
Blue, navy	.20	1.75
Brown, Bismarck	.20	1.00
Chrysoidine, orange	.15	1.25
Coralline	.20	1.75
Green, emerald	.15	1.25
Orange	.20	1.50
Red, Congo	.20	1.75
Red, eosin	.30	2.25
Red, eosine, blue shade	.25	2.25
Red, fuchsine	.20	1.50
Red, rose bengal	.75	6.50
Red, rubin	.20	2.00
Red, saffranine	.20	2.25
Red, scarlet	.15	1.25
Vesuvan	.15	1.25
Violet, gentian	.25	..
Violet, Haffman's	.25	2.00
Violet, purpurin, benzo	.25	..
Violet, purpurin, delta	.25	..
Yellow, mandarin	.25	..
Yellow, metaniline	.25	..
Yellow, naphthol	.20	1.50
Yellow, primuline	.20	1.75
Animal charcoal:		
In grain—10 lb., .07	..	.10
Powder	..	.10
Purified	.10	.50
Annatto	.10	.40
Anthracene, subl. 90%	.15	..
Antimony:		
Metallic	..	.35
Liver of	..	.50
Butter of	..	.26
Aqua Regia	..	.50
Argols	..	.16
Arrowroot:		
Bermuda	.10	.75
St. Vincent	..	.17
Arsenic, metallic	..	.40
Asbestos:		
White, short fiber	..	.40
Washed in nitric acid	.25	1.50
Washed and ignited	.30	2.25
Wool	..	.40
Asphaltum, true	.10	.30
Babbitt metal	..	.35
Balsam:		
Canadian (fir), true	.10	.30
Copaiba	.15	.90

	Per oz.	Per lb.
Balsam *(continued)*		
Fir	..	.30
Peru	$0.35	..
Tolu	.10	$0.45
Banana oil (Lacquer)—qt. .50.		
Barium, metallic—Gram, $12.		
Barks:		Per lb.
Angostura (Galipea cusparia)		$0.60
Barberry (Berberis vulgaris)		.35
Bayberry (Myrica cerifera)		.25
Birch (Betula lenta)		.20
Butternut (Juglans cinerea)		.25
Cinnamon (Cassia cinnamonum)		.25
Ceylon (Cinnamonum zeylanic)		.40
Clove (Cassia Caryophyllata)		.40
Elder (Sambucus canadensis)		.30
Elm, slippery elm (Ulmus fulva)		.30
Lemon peel (Citrus limonum)		.20
Oak, black		.20
Oak, red		.20
Oak, white		.20
Orange peel		.20
Orange peel, cut		.20
Orange peel, ground		.20
Orange peel, powdered		.25
Orange peel, Curacao		.20
Orange peel, ground		.20
Pomegranate (bark of root of Punica granatum)		.40
Sassafras (Sassafras variifolium)		.25
Spicewood (Lindera benzoin)		.25
Wild cherry (Prunus serotina)		.20
Bauxite	..	.30
Bay leaves	..	.15
Bay rum—Gal. $2.75.		
Beans:		
Vanilla	..	4.00
Tonka	..	1.90
Beeswax:		
White	..	.60
Yellow	..	.45
Berlin Blue	.10	.40
Berries:		
Elder (Sambucus nigra)		$0.25
Huckle (Vaccinium myrtillus)		.40
Juniper (Juniperus communis)		.15
Poke (Phytolacca decandra)		.30
Raspberries (Rubus idaeus)		.60
Sumach (Rhus glabra)		.15
Winter cherry (Physalis Alkekengi)		.50
Bismuth, metallic	.35	3.90
Bitumen	..	.25
Black lead	..	.10
Bleaching powder	..	.10

	Per oz.	Per lb.
Bole:		
Armenian	.05	.20
White	..	.15
Bone ash—Finest quality, by 5lb., .09 lbs.	..	.12
Bone black, powdered	..	.10
Brazil wood	..	.15
Bromine	.25	..
Solidified	.25	..
Brunswick black	.10	.70
Burgundy pitch	..	.20
Butter cacao	.10	.70
Cadmium:		
Metallic sticks	.12	1.55
Metallic shells	.25	3.85
Metallic granulated	.35	3.85
Calcium carbide—2-lb. cans, .30.		
Caoutchouc	.15	1.50
For dissolving, pure	.35	3.50
Caramel—Gal., .75.		
Carbon:		
Ground, for pyrotechny	..	.06
Tetrachloride	..	.25
Willow, mealed—10-lb. lots.	.20	.25
Animal, in grain	..	.10
Carborundum	..	.40
Casein	.10	.55
C. P.	.25	3.50
Cassius:		
Purple, of 5%	..	3.50
Purple, of 15%	..	7.00
Catechu	.05	.15
Ceresine:		
White	..	.30
Yellow	..	.25
Black	..	.12
Chalk:		
In lump—10-lb. lots	.04	.05
Precipitated—10-lb. lots	.10	.12
Red—10-lb. lots	.12	.15
French, in tablet—10-lb. lots	.20	.25
Charcoal:		
From blood	.20	2.25
From meat	.25	3.25
From sponge	.10	.85
From wood	..	.10
Chrome gray, orange or yellow	..	.12
Chromium powder, 95%	..	1.50
Cinnabar, pure	.20	1.50
Clay:		
Fire	..	.05
Potters'—Cake, .05	..	.05
Cobalt:		
Blue	..	.25
Ultramarine	..	.20
Foil	1.35	..
Metallic	.50	..

	Per oz.	Per lb.
Cochineal	.10	.75
Cocoa butter	..	.70
Collodion	.10	.95
Collodion cotton	.35	3.25
Colophony, yellow or white	..	.10
Congo red	.20	1.75
Test paper, in sheets—Per doz., .50; each, .05.		
Copper:		
Metallic, turnings	..	.60
Foil	..	.60
Granulated	.10	.60
Powder	.20	2.35
Wire	.10	.86
Coral:		
White, prepared	..	.30
Red	..	.35
Corallin	..	1.25
Cotton:		
Absorbent	..	.30
Non-absorbent	..	.35
Crab apple salt	..	.15
Creosote, white	..	.75
Crocus martis	.05	.20
Composition	..	.08
Crysolite—Gal., $1.		
Cudbear	..	.25
Cumarin	.35	..
Curare—Gram, $1.25.		
Curcumin—Gram, .25.		
Cuttle fish bone:		
Powdered	..	.40
Jewelers'	..	1.00
Dextrin:		
Canary yellow—10-lb. lots, .10	..	.15
Domestic, white (imported, white, lb., .18)	..	.15
Dextrose:		
Glucose, lump	..	.10
Glucose, crystals	..	.15
Diamond inks	.45	4.00
Diamond powder, $1.50 per carat, packed in quarter-carat packages.		
Diastase	.75	..
Distilled water—5 gals., .50.		
Dolomite	..	.30
Dragon's blood:		
In reed	.10	.80
Powder	..	.85
Dutch leaf—Book, .10.		
Elaterium, 1/8 oz., .25.		
Emery flour	..	.10
Medium	..	.10
Coarse	..	.10
Ether:		
Acetic, rectified	.10	.60
Amylic	1.60	..

	Per oz.	Per lb.
Ether (*continued*)		
Butyric, domestic	.15	1.25
Butyric, chem. p., absolute	.35	4.40
Citric	1.70	..
Formic, concentrated, domestic	.22	1.80
Nitric (ethyl nitrate)	.95	..
Œnanthic (oil of cognac), rectified, white	3.75	..
Œnanthic (oil of cognac), nat. green	3.25	..
Œnanthic (oil of cognac), artific., chemically pure	.65	7.50
Sebacylic	.75	..
Succinic	.60	7.15
Valerianic	.40	5.00
Fehling's solution	.10	1.00
Feldspar	..	.10
Fibrin, from blood	.60	..

Essences:	Pint.
Allspice	$0.75
Almond, artif	.75
Anise	1.00
Bergamot	1.00
Cinnamon	.75
Clove	.75
Cognac, artif	3.00
Gin	1.50
Ginger	.70
Jasmine	2.75
Lemon	.75
Orange	.75
Orrisroot	1.00
Peach	1.00
Pear	.75
Peppermint	1.25
Rose	1.50
Rum flavor	2.25
Sarsaparilla	.75
Sassafras	.75
Spearmint	.90
Waldmeister	1.25
Whiskey:	
Bourbon	3.00
Rye	3.00
Wintergreen	1.00

	Lb.
Ferro-Bor.	$7.00
Chrome, 70%	.30
Copper	1.20
Manganese, 85%	.30
Molybdan	3.20
Nickel, 30%	1.40
Nickel, 50%	1.50
Silicon, 36%	.25
Silicon, 75%	.50
Titan	1.50
Tungsten, 67.9%	.75

	Oz.
Vanadium, 10%	$0.40
Vanadium, 25%	.60

	Per oz.	Per lb.
Fire Clay	..	$0.05
Fish glue, liquid—Gal., $1.50.		
Fruit sugar	.35	3.60
Fluorescein	.75	..
Fluorspar	..	.09
Flux:		
Black, Plattner's	.15	1.40
Black, substitute	..	.20
Bismuth	.25	2.40
Boracic acid	.15	1.25
Lead No. 1—5 parts potassium carbonate, 6½ parts sodium bicarbonate, 2½ parts flour, 2½ parts ground borax glass, .25 per lb.; 100 lb. or more, .20.		
Lead No. 2—6½ parts potassium carbonate, 5 parts sodium bicarbonate, 1 part flour, 2½ parts ground borax glass, .25 per lb.; 100 lb. or more, .20.		
Lead No. 3—8 parts potassium carbonate, 2 parts sodium bicarbonate, 1 part flour, 1 part ground borax glass, .25 per lb.; 100 lb. or more, .20.		
Lead No. 4—2 parts potassium carbonate, 2 parts sodium bicarbonate, 1 part flour, 1 part powdered borax, .20 per lb.; 100 lb. or more, .15.		
Fuller's earth, powdered	..	.10
Fusible metal:		
Rose's, melts about 201° F.	.30	3.50
Woods', melts about 141° F.	.30	3.50
Galena	..	.15
Gall nuts	.05	.50
Gamboge	.15	1.25
Gelatin:		
In sheets, white, No. 1, finest	.10	.65
Cooper's	.10	.75
Red	..	1.00
For photographic emulsions.	..	1.25
In sheets, 18 x 18 in., colored, red, blue, green, yellow, orange and purple, per sheet, .25.		
Glass, powdered	..	.20
Glass wool:		
Coarse	.50	6.00
Fine	.65	8.00

	Per oz.	Per lb.
Glucose (grape sugar):		
White, solid	..	.10
Crystallized, pure	..	.15
Syrup	..	.10
Glue:		
Red, best	..	.25
Ground	..	.20
White, No. 1	..	.40
Buffalo	..	.40
Liquid	..	.50
Cologne	..	.18
Fish liquid—Gal., $1.50.		
Marine, hard	.20	2.50
Marine, liquid	.20	1.75
Marine, liquid (colorless)	.30	1.90
Gluten, pure—⅛ oz., .40.		
Goat's blood	..	.35
Gold, metallic—Gram, $2.		
Gold leaf—Book, about .40; varies.		
Graphite:		
In lumps	..	.10
Powdered	..	.20
Lubricating	..	.25
Lubricating, prepared for electrotyping	.10	.50
Gum:		
Ammoniac	.10	.60
Arabic, No. 1	.10	.65
Benzoin	.10	.60
Copal	.05	.45
Damar	..	.35
Elemi	.10	.50
Euphorbium	.10	.40
Galbanum	..	.60
Gamboge	.15	1.25
Guiac	..	.30
Kauri	.10	.60
Kino	.10	.55
Mastic	.10	.75
Myrrh	.10	.50
Olibanum	.10	.35
Sandarac	.05	.35
Senegal	.10	.35
Seed lac	.10	.80
Shellac, orange	..	.75
Shellac, powdered	..	.80
Shellac, bleached	..	.85
Spruce	..	.25
Thus (turpentine)	..	.12
Tragacanth, No. 1	..	1.00
Tragacanth, second grade	..	.80
Guncotton, soluble	.25	2.50
Gutta percha:		
In chips for dissolving	.20	1.75
Tissue—Yard, .55.		
Thin sheets for dissolving, brown	.25	2.00

	Per oz.	Per lb.
Solution, in chloroform	.35	..
Gypsum, lump	..	.10
Hide powder	.40	4.00
Honey	..	.20
Clarified	..	.30
Of roses	..	.50
Hops	.05	.45
Iceland spar, crystals	.20	2.00
Indigo:		
Bengal	.10	1.25
Madras	.10	.65
Indol (indulin), ⅛ oz., .25	1.35	..
Infusorial earth		.10-.15
Insect powder		.25-.35
Invert sugar—Gram, .75.		
Iodine	.30	2.90
Iron:		
Filings	..	.10
Powder	..	.35
Wire, pure	.10	.50
Pyrites	..	.10
Isinglass:		
American	.15	1.20
Russian	.40	4.75
Shredded	.20	1.00
Kaolin:		
White—By 10 lb., .05	..	.10
Washed	..	.20
Kefir fungi	.95	..
Kieselguhr		.10-.15
Kryolite, selected, white	..	.25
Lacquer—Gal., $4 to $5.		
Lactose powder	..	.22
Lampblack—¼ lb., .05; ½ lb., .10		.12-.15
Lead:		
Bars	..	.13
Foil	..	.20
Granulated	.10	.24
Shot	..	.15
Levulose	2.25	..
Lime:		
Marble	..	.10
Burnt	..	.10
Slaked or unslaked	..	.10
Vienna	..	.25
Chlorinated	..	.10
Water—Gal., .35.		
Litmus, best, in cubes	.10	.30
Loadstone	..	.75
Logwood	..	.10
Extract of	..	.25
London purple	..	.25
Luminous paint	.35	3.60
Magnalium	..	1.50
Magnesium:		
Metallic	.35	3.50
Ribbon or wire	.55	6.50
Maltose, pure, cryst	.60	5.50

	Per oz.	Per lb.
Manganese, 92%	.20	..
Marble, dust, chips or lumps	..	.10
Mercury	..	.85
Redistilled	..	.94
Mica:		
Powdered	..	.20
Sheets, as per size		.50 up
Microcosmic salt, C. P.	.10	.50
Mineral wool		.15-.20
Monazite	..	.40
Mosaic gold (bisulphide of tin)	.25	..
Moss:		
Irish	.05	.20
Iceland	.05	.20
Musk:		
Genuine—Grain, .10.		
Artificial	.60	..
Naphthalene:		
Tapers	..	.15
Balls	..	.15
Nessler's test solution	.15	1.10
Nickel:		
Metallic, 90%	.10	1.00
Foil	.20	1.95
Wire	.20	2.00
Anodes (of cast nickel)	..	1.20
Anodes (of cast nickel), 10 lb. or more	..	1.10
Anodes (of cast nickel), 50 lb. or more	..	1.00
Anodes (of cast nickel), 100 lb. or more	..	.90
1¾ x 4 x 3-16 inches, ½ lb.; 3 x 8 x 5-16 inches; 2¼ lb.; 4 x 8 x ½ inches, 4½ lb.; 8 x 16 x ½ inches, 18 lb. (Weights are approximate.) Add 10 cts. per lb. for these small sizes. Larger sizes furnished to order.		
Nutgalls (powdered, lb. .50)	.05	.40
Nuts, kola	.10	.40
Oakum	..	.13
Ocher	..	.05
Oil:		
Almond	.60	6.50
Artificial	..	1.00
Amber, crude	.10	.50
Amber, rectified	.05	.35
Anise	.20	2.00
Asphaltum	..	4.25
Bay	.04	4.70
Bergamot	.40	..
Cedar	.10	1.10
Cloves	.20	1.75
Coconut	.25	..

	Per oz.	Per lb.
Oil (*continued*)		
Cognac	6.00	..
Cottonseed—Gal., .75.		
Fish—Gal., .50.		
Fusel—Qt., .50; pt., .30.		
Lard	..	.20
Lavender	.20	1.75
Lemon	..	1.50
Linseed, raw	..	.15
Linseed, boiled	..	.15
Myrbane	..	.20
Neatsfoot—Gal., $1.		
Neroli (orange flowers), bigarade, ⅛ oz., .75.		
Olive	..	.40
Orange, finest	.30	..
Orris, ⅛ oz., .75.		
Palm	..	.25
Paraffine—Gal., .40	..	.10
Peach kernels	..	.40
Peanut	..	.40
Pear (amyl-acetate), pt., .75.		
Peppermint	.40	5.00
Petroleum, crude—Gal., .35.		
Rose (Kezanlic), ⅛ oz., $1.25.		
Rosin—Gal., .45	..	.10
Sandalwood	.50	5.00
Sassafras	.10	.75
Sesame—Gal., $1.75.		
Sperm	..	.20
Tar	..	.15
Tobacco	1.40	..
Turkey red	.10	.50
Turpentine (rectified)	.25	..
Wax	.25	..
Whale	..	.20
Wintergreen	.20	1.90
Ylang-Ylang	6.20	..
Orpiment	..	.25
Oxgall	.25	..
Oyster shells	..	.15
Ozokerite	..	.30
Paper:		
Emery—Quire, .35.		
Paraffine—Quire, .25.		
Parchment—Quire, .35.		
Sand—Quire, .25.		
Wax—Quire, .35.		
Litmus, blue, in sheets, each .05; doz., .50.		
Turmeric, in sheets, each .05; doz., .50.		
Paraffine:		
Pure white, hard, melting point, 130° F. or 55° C.	..	.15
Liquid	..	.20
Paris green, pure	..	.40
Paris white	..	.05
Pearlash	..	.10

	Per oz.	Per lb.
Petrolatum:		
Yellow	..	.15
White	..	.25
Phosphorus, yellow sticks	.24	1.25
Pipe clay	..	.10
Pitch:		
Black	..	.10
Burgundy	..	.20
Plaster of paris	..	.10
Platinum foil wire, etc.—Gram, $1.27-$1.50; fluctuates.		
Plumbago:		
In lumps	..	.20
Powdered	..	.20
Fine powder for electrotyping	.10	.50
Potassium, metallic	1.70	22.50
Potter's clay—Cake, .05.		
Powdered	..	.05
Primuline	.20	1.75
Prussian blue	.10	.55
Soluble in water	.10	.60
Pumice stone—10 lb., .08	..	.10
Powdered, fine, 10 lb., .07	..	.10
Purple of Cassius, C. P., ⅛ oz., $1.75.		
Putty powder	.25	2.90
Pyroxylin	.25	2.50
Quartz, powdered	..	.10
Realgar	..	.25
Red lead	..	.10
Rennet	..	..
Resin, white or yellow	..	.10
Resorcin, cryst., white, pure	.15	..
Retinol	.70	..
Rhodium—5-grain vial, $2.50.		
Rice flour	..	.25
Rock salt	..	.10
Rosin:		
By 5 lb., at .05	..	.06
Powdered	..	.18
White—By 5 lb., at .08	..	.15
Rotten stone	..	.10
Powdered	..	.15
Rouge:		
Jeweler's, best French	.13	1.20
Soft gold	.10	.95
Soft gold, 50 lb. or more	..	.90
Hard nickel	.10	.27
Hard nickel, 50 lb. or more	..	.25
Soft nickel	.10	.55
Soft nickel, 50 lb. or more	..	.50
Soft silver	.10	.95
Soft silver, 50 lb. or more	..	.90
Hard silver	.10	.90
Hard silver, 50 lb. or more	..	.85
Rush, scouring	..	.25

	Per oz.	Per lb.
Salt:		
Sea	..	.10
Sorrel	..	.25
Schlippe's	.25	..
Scheele's green	.10	.75
Sealing wax:		
Fine red, in sticks	..	.75
Common, bottle wax	..	.10
Selenium, sticks	1.80	22.00
Sienna, raw or burnt	..	.08
Silex	..	.04
Silica:		
In fine powder		.10-.12
Precipitated, pure	.10	.75
Silver:		
Granulated	1.25	..
Foil	1.25	..
Leaf—Book, .20		
Anodes	1.20	..
Soapstone, powder	..	.04
Sodium, metallic	.15	1.20
Soot	..	.20
Spar, heavy (barite)	..	.10
Spermaceti	..	.45
Stains—$1 gal. up.		
Starch:		
Corn		.10-.15
Iodized	.25	..
Potato		.10-.15
Wheat	..	.15
Stearine	..	.35
Steel filings	..	.15
Sugar:		
Cane, C. P.	..	1.00
Grape	..	.10
Sugar milk:		
Crystallized	..	.35
Powdered	..	.35
Sulphur:		
Roll—By 25 lb., lb. .05	..	.08
Sublimed (flowers), by 25 25 lb., lb. .07.		
Precipitated	..	.20
Washed	..	.15
Sumac	..	.15
Talc	..	.15
Powdered, in quantity	.04	.10
Tallow	..	.25
Tar:		
Barbadoes—Gal., .60.		
Strained—Pint can, .25; 2-gal. can, $1.		
Terebene, pure	.10	.65
Terra alba	..	.10
Test paper, litmus paper, blue and red, turmeric. Brazil-wood, Congo, lead acetate, per sheet, .05; per doz.,		

	Per oz.	Per lb.
Test paper, etc. (*continued*) .50; per book, .05; per box (10 books), .25; narrow books (24 in box), per box, .30.		
Thermit:		
Black	..	.90
Red	..	.75
Thymol, cryst., pure, white..	.30	3.25
Tin:		
Bars	.10	.55
Granulated	.10	.75
Foil, thin	..	.37
Foil, heavy	..	.31
Foil, pure	..	.70
Amalgam	.45	5.60
And zinc amalgam	.30	4.00
Tripoli powder	.10	..
Tungsten:		
Metallic, pure—Gram, .20.		
For steel manufacture	.15	1.10
Turmeric:		
Powdered	..	.20
Paper—*see Test paper.*		
Turpentine:		
Spirits—Gal., .80; pt., 15.		
Spirits, refined—Gal., $2; pt., .40.		
White, hard, select	..	.15
Venice		.25-.40
Ultramarine, artificial	..	.25
Vanillin	.60	..
Varnish:		
Amber—Gal., $8.		
Asphaltum—Pt., .20; gal., $1.25.		
Black, for iron—Pt., .20.		
Bronzing liquid—Gal., $1.35.		
Copal, best—Pt., .50.		
Dammar — Pt., .35; gal., $1.75.		
Flowing—Gal., $2.50.		
Gold size—Gal., $4.		
Negative, photographers', 8-oz. bottle, .50.		
Picture—Gal., $1.25.		
Spar—Gal., $4.		
White enamel—Gal., $2.75.		
Verdigris:		
Powdered	.05	.50
Recryst., pure	.10	.70
Vermillion:		
Chinese	.15	..
English	.12	1.50
Vesuvin	.15	1.25
Vienna lime, lump or powdered	..	.20

	Per oz.	Per lb.
Wax:		
Beeswax, yellow, technical (by 5 lbs., .45)	.05	.50
Beeswax, pure (by 5 lb., .60)	.10	.65
Beeswax, white (by 5 lb., .60)	.10	.60
Carnauba (Brazil) (by 5 lb., .50)	.10	.55
Japan	..	.30
Myrtle	..	.50
Ozokerite	..	.18
Paraffine	..	.15
Sealing wax, bottle wax	..	.10
Sealing wax, fine, sticks	..	.75
Water, distilled (by 5 gals., .50); gal., .10.		

Water:	
Almonds, bitter	$1.00
Caraway	.25
Cherry laurel	.30
Cinnamon	.20
Cologne	1.00
Dill	.20
Elderflower	.50
Javelle—Gal., .50	.10
Lavender	.40
Lime—Gal., .50	.10
Orange flower—Gal., $1.50	.25
Peppermint	.25
Raspberry	.30
Tar	.20
Wintergreen	.25

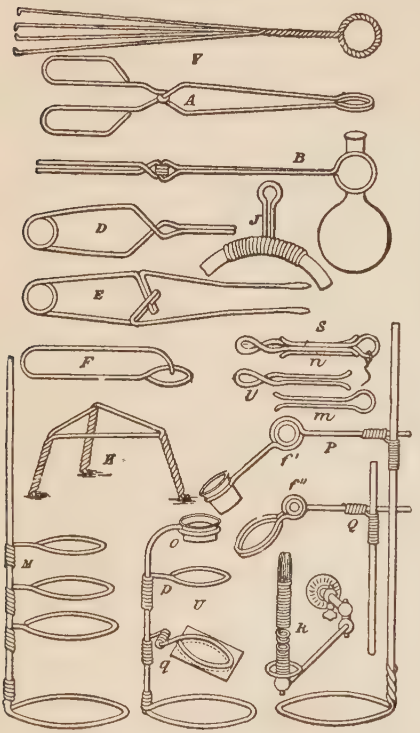
	Per oz.	Per lb.
White acid in ceresine bottle.	..	.70
White lead	..	.10
Whiting (by 25 lb., lb. .02½).	..	.05
Wool:		
Glass	.75	..
Mineral	..	.15
Steel—Fine, lb., .80	..	.65
Zaffre	.10	.75
Zinc:		
Sl[illegible]ps	..	.15
Sheets	..	.20
Granulated	..	.22
Powdered	..	.25
Amalgam	..	.60

LABORATORY APPARATUS

Wire Apparatus for Laboratory Use.

For most of the apparatus shown, some oxidizable wire should be selected, such as brass or tinned iron, and the tools for forming these articles of wire consist of a pair of cutting pliers, a pair of flat and a pair of round-nosed pliers, a few cy-

lindrical mandrels of wood or metal, made in different sizes, and a small bench vice. Any or all of the articles may be in different sizes, and of different sizes of wire for different purposes.

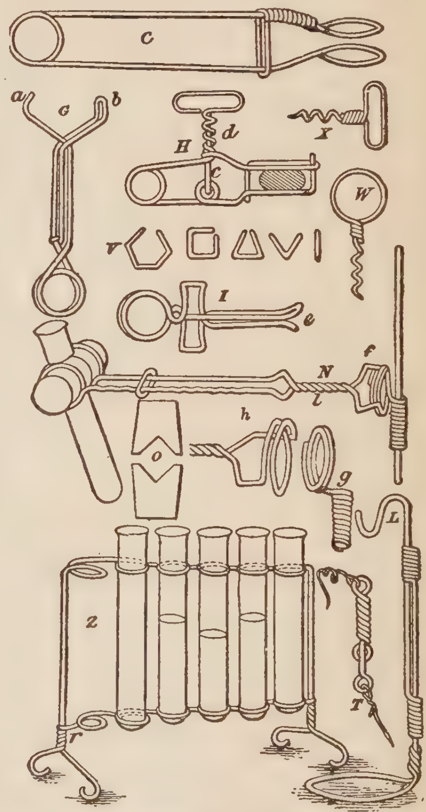


Wire Apparatus for Laboratory Use

A shows a pair of hinged tongs, which are useful for handling coals about the furnace, for holding a coal or piece of pumice for blowpipe work, and for holding large test tubes and flasks, when provided with 2 notched corks, as shown in B and O. These tongs are made by first winding the wire of one half around the the wire of the other half to form the joint, then bending each part at right angles, forming on one end of each a handle, and upon the other end a ring. By changing the form of the ring end the tongs are adapted to handling crucibles and cupels and other things in a muffle.

C shows a pair of spring tongs, the construction of which will be fully understood without explanation. It may be said, however, that the circular spring at the handle end is formed by wrapping the wire around any round object held in the vice; the rings at the opposite end are formed in the same way. The best way to form good curves in the wires is to bend them around some suitable mandrel or form.

D shows a spring clamp for holding work to be soldered or cemented. It may also be used as a pinch cock.



Wire Apparatus for Laboratory Use.

E represents a pair of tweezers, which should be made of good spring wire flattened at the ends. F is the clamp for mounting microscope slides, and for holding small objects to be cemented or sol-

(Laboratory Apparatus)

dered. G is a pinch cock for rubber tubing; its normal position is closed, as in the engraving, but the end *a* is capable of engaging the loop *b*, so as to hold the pinch cock open. H shows a clamp or pinch cock having a wire *c* hooked into an eye in one side, and extending through an eye in the other. This wire is bent at right angles at its outer end to engage a spiral *d*, placed on it and acting as a screw. The open spiral is readily formed by wrapping 2 wires parallel to each other on the same mandrel, and then unscrewing one from the other. The handle will of course be formed by aid of pliers. I shows still another form of pinch cock. It is provided with 2 thumb-pieces, which are pressed when it is desired to open the jaws. K is a tripod stand, formed by twisting 3 wires together. This stand is used for supporting various articles, such as a sand bath or evaporating dish, over a gas flame. It is also useful in supporting charcoal in blowpipe work.

L shows a stand adjustable as to height for supporting the beak of a retort, or for holding glass conducting or condensing tubes in an inclined position. The retort or filter stand, represented in M, is shown clearly enough to require no explanation. Should the friction of the spiral on the standard ever become so slight as to permit the rings to slip down, the spirals may be bent laterally, so as to spring tightly against the standard. N shows an adjustable test tube holder, adapted to the standard shown in M, and capable of being turned on a peculiar joint, so as to place the tube in any desired angle. The holder consists of a pair of spring tongs, having eyes for receiving the notched cork, as shown in O. One arm of the tongs is corrugated to retain the clamping ring in any position along the length of the tongs. The construction of the joint by which the tongs are supported from the slide on the standard is clearly shown in O *a*. It consists of 2 spirals *g h*, the spiral *h* being made larger than the spiral *g*, and screwed over it, as shown in O. This holder is very light, strong and convenient.

P represents a holder for a magnifier, which has a point *f′*, similar to the one just described. The slide *k* is formed of a spiral bent at right angles and off-set to admit of the two straight wires passing each other. This holder may be used to advantage by engravers and draughtsmen. Q shows a holder for a microscope condenser, the difference between this and P being that the ring is made double to receive an unmounted lens.

R shows a Bunsen burner, formed of a common burner, having a surrounding tube made of wire wound in a spiral, and drawn apart near the top of the burner to admit the air, which mingles with the gas before it is consumed at the upper end of the spiral.

S represents a connector for electrical wires, which explains itself. The part with a double loop may be attached to a fixed object by means of a screw. Another electrical connector is shown in T, one part of which consists of a spiral having an eye formed at each end for receiving the screws which fasten it to its support, the other part is simply a straight wire having an eye at one end. The connection is made by inserting the straight end in the spiral. To increase the friction of the two parts, either of them may be curved more or less.

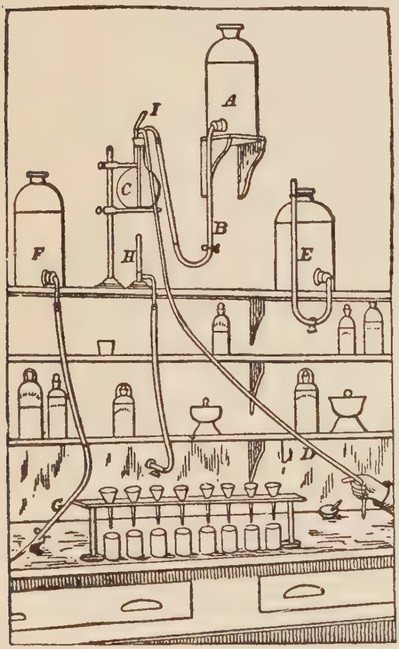
A microscope stand is shown in U. The magnifier is supported in the ring *o*. The ring *p* supports the slide, and the double ring *q* receives a piece of looking-glass or polished metal, which serves as a reflector.

V shows a set of aluminum grain weights in common use. The straight wire is a 1 gr. weight, the one with a single bend is a 2 gr. weight, the one having two bends and forming a triangle is a 3 gr. weight, and so on. W and X are articles now literally turned out by the million. It is a great convenience to have one of these expensive little corkscrews in every cork that is drawn occasionally, thus saving the trouble of frequently inserting and removing the corkscrew. The cork puller shown in Y is old and well known, but none the less useful for removing corks that have been pushed into the bottle, and for holding a cloth or sponge for cleaning tubes, flasks, etc.

Z shows a stand for test tubes. The wire is then formed into a series of loops, and twisted together at *r* to form legs. A very useful support for flexible tubes is shown in J. It consists of a wire formed into a loop, and having its ends bent in opposite directions to form spirals. A rubber tube suported by this device cannot bend so short as to injure it. Most of the articles described above may be made to the best advantage from tinned wire, as it possesses sufficient stiffnsss to spring well, and at the same time is not so stiff as to prevent it from being bent into almost any desired form. Besides this the tin coating protects the wire from corrosin, and gives it a good appearance. —George M. Hopkins.

Wash Bottle.

By this simple device the washing of precipitates and the cleansing of vessels used in the process of analysis, which before required the use of the ordinary wash bottle, can now be done with much more facility and in a shorter time. It consists essentially of a thin glass flask C, placed about 3 ft. above the level of the working desk, and closed by a 3-hole rubber stopper. Through one of the holes issues a rubber tube D (or glass with rubber connections), descending to the desk and ending in a glass nozzle. Connection is made by a second hole in the stopper with a reser-



Laboratory Table Showing Wash Bottles.

voir bottle A, placed above the top of the wash bottle. In the third hole is placed a glass tube bent at an angle to keep out dust. On filling the flask from the reser- by a pinch cock placed conveniently to the hand, the height of the water flask voir—the flow being stopped by a pinch cock—the water is started by suction from below, and the stream through the nozzle can be regulated or stopped at will furnishing the pressure, which is sustained by the syphon.

A Bunsen burner H is placed underneath the flask, and the water can be heated when it is so desired. Hot water as well as cold can thus be used in treating precipitates. Other solutions can be employed equally as well as water. (See bottle F.).

The advantages of the system are:

1.—The saving of much time and consequent labor attending the use of an ordinary wash bottle, especially where several analyses are carried on at the same time, the exertions required by the mouth and lungs being thereby avoided.

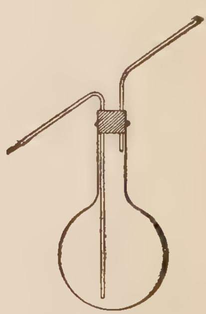
2.—No air exists in the tube, as in an ordinary wash bottle, and consequently the full force of the liquid is utilized immediately.

3.—When used with a wash solution of ammonia water, no trouble is experienced with free ammonia, which ordinarily is quite hurtful to the mouth and eyes.

The large bottle E with the accompanying tube shows a convenient arrangement for holding any solution and delivering the same.

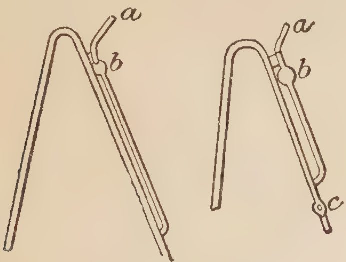
The shelves of a laboratory should be widest at the bottom and should become of less depth at the top to accommodate smaller bottles. The large acid bottles should be put on the bottom shelves. Reagent bottles with the names and symbols blown in are very convenient.

A wash bottle is easily constructed with the aid of a couple of glass tubes and a flask or any bottle of convenient size. One of the glass tubes should be drawn out to the fine point, and the other should be inclined so that it is easily introduced into the mouth. Any desired quantity of water may be forced through the fine powder by moderate blowing. In some


Wash Bottle

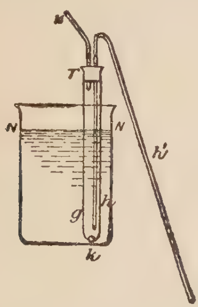
cases the wash bottle is more efficacious when warm. For fine chemical work still water should preferably be used.

Syphons.—Our engravings show handy glass syphons adapted for small operation, the former being without, the latter with stop cock *c* for regulating the flow.



Glass Syphons.

The current is started in these by applying the mouth to the end *a* of the tube, and employing it as an air pump to exhaust the air till the fluid rises into the bulb *b*. With harmless liquids, a simple

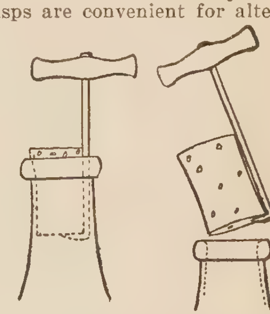


Improved Syphon.

bent glass tube may suffice as a syphon; but suction with the mouth at the end of the longer arm is somewhat inconvenient. The arrangement shown above is simple, and presents certain advantages: A glass tube *g*, ¾ in. wide, and 12-16 in. long, contracted at the lower end, has, at its upper end, a cork stopper, in which the mouthpiece M and the syphon *h h'* are fixed air-tight. The shorter arm *h* of the syphon reaches nearly to the bottom of the tube, and limits the play of a glass ball *k*, which acts as a valve. The diameter of the ball is about ½ in., that of the syphon ¼ in. The instrument thus arranged, being dipped into the vessel to be discharged, the tubes *g* and *h* become filled with liquid to the surface N N. Instead of now sucking, as with the common syphon, one blows into the mouth-piece M; and in consequence of the compression of air, the lower opening is shut by the ball *k*, while the liquid rises in *h*, and begins to flow through *h'* in the usual way. If the vessel to be emptied is not full, or the column of liquid is a small one, it is necessary before blowing into the mouthpiece, to suck it slightly, in order to obtain a larger volume of the liquid in *g*; as one condition for the right action of the instrument is that *h h'* should be filled before the column of liquid in *g* sinks to the mouth of the syphon at *k*, when one blows through M.

Cork Work

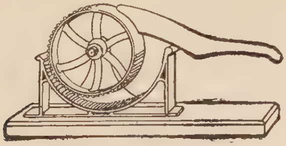
Corks are of the greatest possible use in all laboratories. Boxes of corks may be had of all drug companies and a plentiful supply should be kept at all times. It would probably be necessary to buy larger corks separately. It is frequently necessary to perforate corks, and for this purpose a set of cork borers should be bought; they come in sets. An iron rod passes through the small holes, forming a handle. A rotary motion should be given to the hand at the same time pressure is applied. There is considerable knack in boring corks, but it is soon attained. After the glass tubes have been passed through the corks the corks can be swelled to insure a firm joint. Files and rasps are convenient for altering the



Cork Puller.

shape of corks. Rubber corks are very expensive, but are better for many purposes. They may be purchased already perforated. The ordinary cork borer may, however, be used, wet with dilute ammonia. Pieces of rubber tube of various sizes, and also pieces of hog's bladder for joints, and heavy linen thread for tying the same, should always be at hand.

A cork press will save its cost in a short time. The form shown in our en-

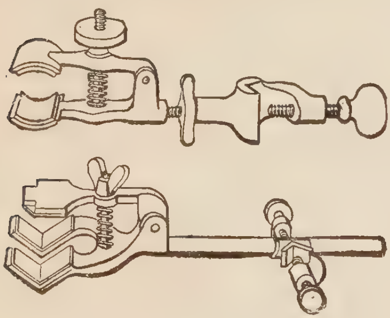


Cork Press.

graving is very effective. Corks which have been compressed give better results than those which are used dried. In the type of press shown, the cork is revolved at the same time it is being compressed, thus giving a uniform compression. Corks having a taper should be selected.

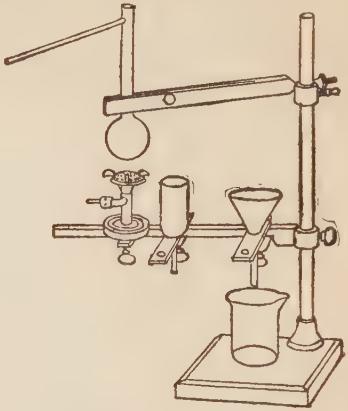
Stands, Clamps, etc.

The amateur who has a shop at his disposal will have little difficulty in constructing all necessary supports, which



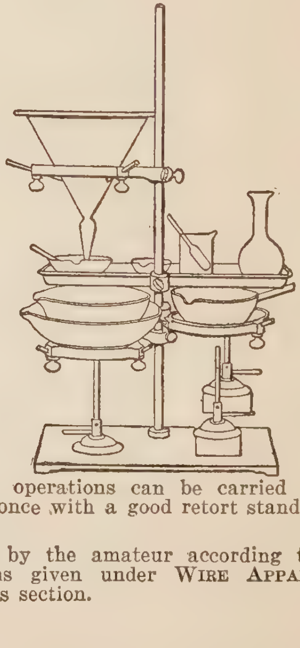
Clamps for Various Purposes.

will tend to materially assist his labors. To those who have no natural mechanical ability, or who have no facilities, are recommended to purchase such apparatus ready prepared of dealers in chemical supplies. A good retort stand is of prime importance, and one of our engravings shows how a retort stand may be used for several purposes at once. Iron retort stands are better than the wooden ones, and there should be at least 4 or 5 rings. The base should be of sufficient weight to make the stands firm at all times. If the base of the retort stand is too light it can be filled with lead. Our engravings also show a variety of clamps which are very useful for a great number of purposes; at least 2 or 3 such clamps should be provided. Nearly every dealer in chemical apparatus lists 15 or 20 different types at all prices. Where rubber tubes are used, pinch cocks will



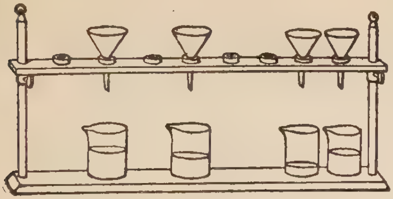
Simple Retort Stand.

be found of value in cutting off the supply of the gas. They can be readily

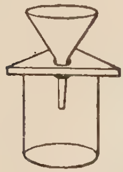


Many operations can be carried on at once with a good retort stand.

made by the amateur according to the designs given under WIRE APPARATUS in this section.



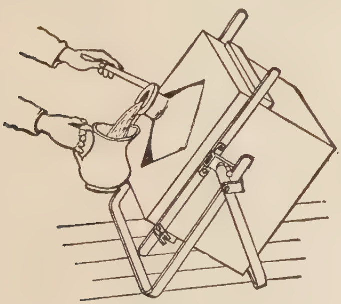
Simple Filter Holder.



A Triangular Holder.

Measuring Liquids.

Liquids may be measured in dishes or containers, of which there are a large number of patterns. The writer recommends the Swedish white enameled ware



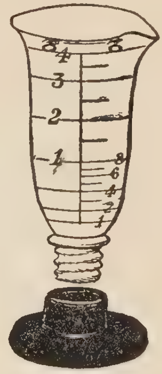
Carboy Tilting Stand.

as indicating at once if there is any dirt in the article. Almost any large dealer in household furnishings would be able to supply a large number of vessels for measuring liquids required by technologists and chemists. Copper measures last a long time, but are very hard to keep clean. They are good for alcoholic liquors. A porcelain measure with graduations inside is very useful. An article of this kind will save its cost in a short

(Measuring Liquids)

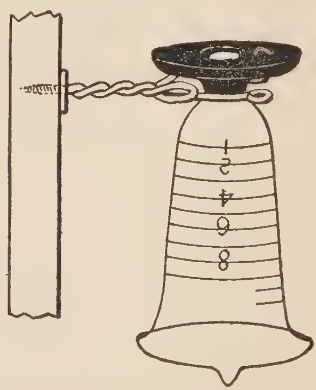
time for much work that is done in a laboratory.

Glass graduates form an essential part of the equipment of all laboratories, no matter how small or for what purpose.



Graduate with Rubber Foot.

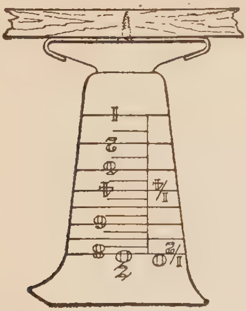
Glass graduates of 2, 4, 8, 16, and 32 oz. are recommended. The chemical graduates are easier to get clean than the cylindrical ones. Glass graduates having a beaker shape lessen the liability of



Graduate Suspended from Wire Hook.

breakage and are especially good for 16 and 32-oz. sizes. Some graduates have a double scale, both apothecary's and metric; these are specially recommended where mixed formulas are used calling for

both systems. Their use will save much time and calculations, and are specially useful in photographic work where many of the formulas are now given exclusive-



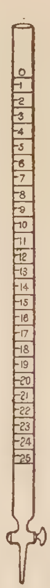
Graduate Slung under Shelf.

ly in metric system. A graduate is "no stronger than its foot," and this is the most vulnerable part of the glass measures. Rubber feet with the screw socket into which the top of the graduate screws have come into quite general use, and are recommended as they tend to decrease the breakage to a considerable extent. When graduates are not in use they should be hung up by the foot, as illustrated in one of our engravings.

For beginning with small quantities of liquids the pipette is recommended, and the simplest form is like the well-known fountain pen filler. Small pipettes can be obtained shaped like a fork so that they can be used as such in small bottles. For volumetric work and for other accurate determinations, graduated pipettes are sold, but they are comparatively high in price. Small drops of liquid can be readily drawn out of a bottle and distributed with the aid of the pipette. The drop, however, is different from almost every substance, and the number of drops a minim varies from 60 to 250. An excellent table showing the number of drops in a fluid dram of different weights with the weights in grains and grams will be found in Remington's Practice of Pharmacy.

Scales.

A good ordinary scale costing from $6 to $10 is recommended. Scales should have a capacity of at least 10 lb. Any sensitive weighing such as required in analytical work, assaying, etc., should not be attempted with scales of this kind. Where corrosive substances which would corrode metal scale pans are in use, the glass tanks should be used, or the substance should be weighed in glass bottles or other containers.



Pipettes.

The Balance is simply a pair of scales, made and adjusted so carefully as to show very small differences in weight of two substances.

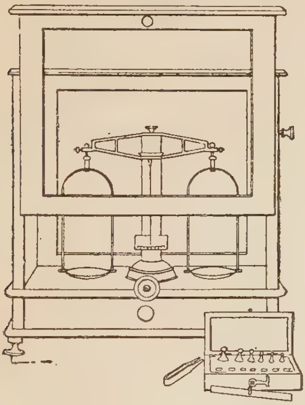
The beam is supported in the middle by a wedge of hard steel, or of agate—a "knife-edge"—resting in a very shallow groove, also of steel. A similar arrangement is used for supporting the scale pins, but in this case the knife-edge is on the end of the beam. The steel should be protected by a very thin coating of vaseline.

By turning the screw placed outside the balance case, the beam may be raised so as to allow it to swing, or lowered so as to prevent any motion. When not in use it should always be lowered.

A pointer is fixed to the middle of the beam, and when the beam is swinging, the end of this pointed moves over a white graduated scale. When the two pans balance, the pointer will move over the

same number of divisions on each side of the zero position.

The weights to be used range from 50



A Balance of Precision.

grams to 1 milligram. The weights below 1 cgrm. may be made of aluminum wire. Each weight should have a separate place in the box. The weights are arranged as follows:

grams.	grams.	grams.	grams.	grams.
50	5	0.5	0.05	0.005
20	2	0.2	0.02	0.002
10	2	0.1	0.01	0.001
10	1	0.1	0.01	0.001

Rules to be Observed in Weighing:

a.—Put the weights on the right-hand pan of the balance.

b.—Never put anything on the balance pans, or take anything off, while the balance is free to swing.

c.—Always use the forceps provided for lifting the weights.

d.—On commencing to weigh, find a weight which is too great, then, after removing this, try the succeeding weights in order. Never pick out weights at random.

e.—Do not put the small weights in a heap. Arrange them in order round the larger weights, which should be in the center of the balance pan.

f.—Place yourself opposite the center of the graduated scale while weighing.

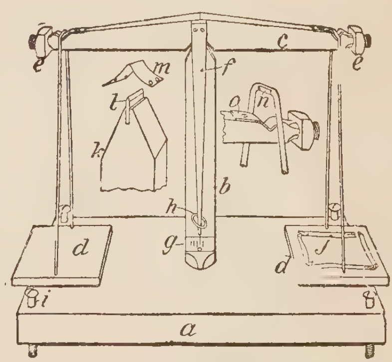
g.—Do not remove any weight from the balance pan until the values of all have been written down, and check your result as the weights are replaced.

h.—Be careful to put the weights back in their proper place.

i.—Never attempt to weigh anything which is not quite cold. In addition to injuring the balance, the weighing will not be accurate.

This mode of pulverization, though particularly applicable to fibrous substances, is sometimes used for metals and hard materials. In the latter case the files may have finer and sharper teeth, and in both instances be particularly clean, and free from grease and dust.

To Make a Balance.—A balance suitable for weighing small articles can be made easily and cheaply. Such a balance can be made sensitive to the weight of one-quarter of a postage stamp, and capable of sustaining a weight of several ounces. It is made chiefly of wood. All the parts are common articles, and only ordinary tools are required. Only certain features require careful attention; in other respects, rough work is permissible, says "School Exercises in Plant Production," by D. J. Crosby, in Farmer's Bulletin No. 408. The essential parts of a balance (see cut) are the base (*a*), the pillar (*b*), the beam (*c*), and the trays or pans, as they are usually called (*d*, *d*). The beam is balanced by means of the balancing nuts (*e*, *e*). The pointer (*f*) indicates on the scale (*g*) the effect of weights on the trays. A screw-eye (*h*) encircling the pointer serves to hold the



A Simple Balance

beam at rest, or permits it to swing, as desired, according as the screw-eye is turned. Four screws (*i*) at the corners of the base serve to level the balance.

In making the balance thoroughly dry, soft pine wood is preferable. Screws are

preferable to nails. The base is 12 or 14 in. long by 7 in. wide and 1 in. thick. The pillar is 1 in. square and about 9 in. high. It can be set in an inch hole in the center of the base. Care should be taken to have it stand perpendicular to the base. The upper end of the pillar is beveled on the right and left sides, as shown at *k*. A slot is sawed in the end to receive a knife edge, as shown at *l*. The beam is made from a stick 1 in. square and about 10 in. long. Its lower face is left straight; the other faces are beveled from the center to the ends, which are left ⅜ or ½ in. square. A notch 1 in. wide and ½ in. deep is accurately cut in the center of the flat or bottom face. This receives the central bearing (*m*) of the beam. An inch from each end of the beam a notch ¼ in. deep is cut to receive the tray bearings. Each end is rounded to receive the balancing nuts. The nuts should cut well defined threads in the wood and move easily and smoothly. Applying a little soap to the threads helps this. A strong pointer (*f*) is firmly fastened to the beam by two or more screws. Its lower end is provided with a needle, colored black so as to be readily seen. The screw-eye (*h*) is placed near the end of the pointer and in the center of the pillar. It should turn easily and smoothly. When the balance is otherwise completed, turn the screw-eye so as to hold the pointer firmly, then paste to the pillar back of the pointer a strip of white paper (*g*) bearing scale marks, 1-16 in. apart, with the 0 mark of the scale directly back of the needle.

The three bearings of the beam are the most exacting features of the construction. Each consists of a knife edge, acting within a groove formed of bent tin. The knife edge (*l*) for the central bearing may be made of a pocket or case knife blade, or of a piece of hard brass filed to a straight, sharp edge. The knife edges for the end bearings are made by filing the lower side of the tray wires where they cross the beam, producing a straight, sharp edge (*n*) about ¾ in. long. The tins forming the grooves of the bearings are made of thin tin, such as is used in oyster and vegetable cans. Bright pieces are selected. The central bearing requires a strip 1 in. wide and 2 in. long (*m*). It is bent across at the middle, the bend being lightly hammered flat on a flatiron. The ends are then separated. The halves of the strip curve somewhat, leaving a narrow angle at the bend. This tin is firmly held in the central notch of the beam by four small screws. The tin strips for the end bearings are about ½ in. wide. They are bent in the same way as the other. One end of the strip is longer than the other, and is punched to receive a single screw holding it to the beam, as shown at *o*. The bending of the tin strips roughens the surface of the groove. It must be polished by rubbing the back of the point of a knife blade back and forth in the groove for some time. To insure success, the grooves must be very narrow to prevent side slipping, yet not so narrow as to bind on the knife edge. The highly polished groove and sharp knife edge produce the least friction, and increase the sensitiveness of the balance.

The trays are made of common No. 12 wire. The trays are 3 by 3 in. and ¼ in. thick. Two holes near opposite edges receive the wires, which are bent in opposite directions beneath the trays, thereby holding them firm and level. If the trays tend to swing from front to back of the balance, the tins of the bearings may be slightly twisted by inserting a knife blade under them.

The balance can now be tested for use. When in working condition the pointed will slowly swing back and forth many times, and finally come to rest at 0 of the scale. It probably will not do this at the first trial. Set the balancing nuts at about equal distances from the ends of the beam, then stand tacks along the lighter beam arm until the two arms nearly balance. The tacks are then driven in permanently. If tacks are too light, use brads or screws. The final balancing can then be done by properly moving one or both of the nuts. The proper adjustment of the balancing nuts should be tested each time the balance is used.

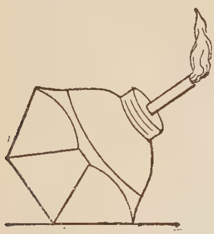
Weights, and objects to be weighed, can be held on the trays by cardboard dishes (*j*). A pair of forceps can be made from a strip of spring brass, or even of hickory wood, the points being properly sharpened.

A set of metric weights ranging from 20 grams to 1 centigram, and suitable for use with this balance, can be had for $1 or less.

Fuels.

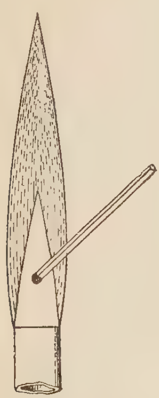
The technologist has a wide choice of fuels at the present day. In certain localities wood is plentiful and is well adapted for various processes. It is, however, very sooty and cannot be used for many purposes. Charcoal is much in use and is not expensive. It can be used freely when a quick, strong heat is re-

quired. Coal is an excellent fuel for general purposes. Anthracite coal is better now for general use than bituminous coal, although the latter makes the hotter fire. The deposit of soot is often very objectionable. Coke may be had almost anywhere and affords a clean, hot fuel. It is easily kindled. Gas is perhaps the best all-round medium for the production of heat, except where manufacturing operations are to be carried on. A large number of devices calling for the use of gas



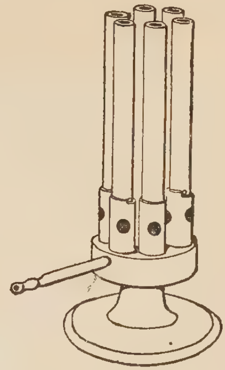
A Convenient Alcohol Lamp.

are illustrated in the present book. The Bunsen burner is perhaps the most generally used type of burner. The flame should be blue, and the air regulation is usually accomplished by a ring at the bottom. There are scores of types of

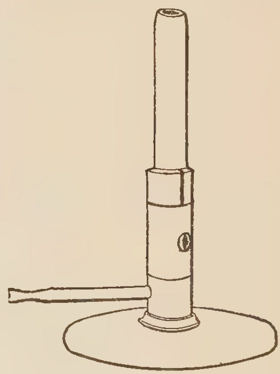


The Blowpipe Flame.

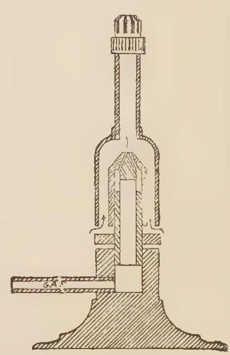
Bunsen burners. For very intense heat the multiple Bunsen burners are recommended. Radio burners using the Bunsen principle are largely used in all of the mechanical arts. Gas can also be used to



Multiple Bunsen Burner.



A Simple Bunsen Burner

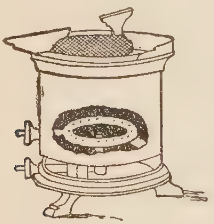


Improved Bunsen Burner.

drive a small hot-air engine for small power laboratories. There are many apparatus which give increase by stirring or agitating where a small caloric engine, or water or electric motor, can be used to advantage. All of the dealers in chemical apparatus furnish petroleum, gasoline and benzine burners as well, so that those who are away from large cities or towns will find their wants very well supplied.

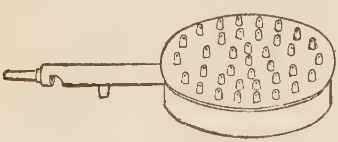
Where considerable quantities of hot water are required, a hot water heater run preferably by gas should be provided. They are not so expensive, and produce large volumes of hot water at moderate cost. Perfect control and safety of gas has a great deal to recommend it.

Electricity, though well adapted for all classes of technical work, is very little used owing to the great expense of the initial apparatus and the cost of current, and the length of time which is also required to heat up the hot plate or other device militates against the use of elec-



Burner for Slow Heat.

tricity. The writer has used electrical stoves for heating purposes, and he cannot see that they are of any advantage over hot plates heated by gas. Should it be desired, however, to install electrical apparatus, great care should be taken when



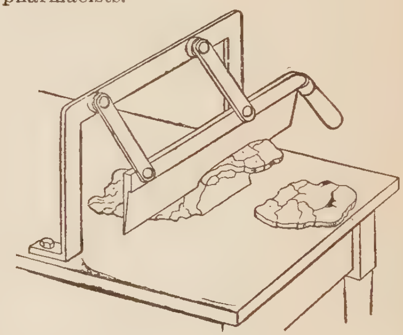
A Good Type of Burner for Evaporation

ordering the equipment that the voltage is the same as the feed mains, as otherwise the electrical apparatus will surely be destroyed.

The blowpipe and charcoal are very useful things to have about the laboratory in connection with the Bunsen burner. Numerous small operations can be conducted with their aid. Blowpipe analysis is a very valuable means of determining minerals and other substances.

I
COMMINUTION OR DIVISION OF SUBSTANCES

This operation is a mechanical process, by which the surface and points of contact of solid bodies are multiplied, thus diminishing the force of cohesion, and consequently promoting greater access to its particles, and enabling a more ready and rapid action of reagents upon solid matter. The means by which the division of solid matters is accomplished are manifold, and those who are using technical formulas will often have to resort to methods which are not in use even by pharmacists.



Draw Knife Slicer

Slicing.

This process applies to fibrous matters, and is largely practiced with a lever knife similar to that used by tobacconists for cutting tobacco. This slicing renders the substance in better form for maceration, and, moreover, admits of readier desiccation, a necessary process when it is required to be further reduced under the pestle or by being grated on a coarse rasp. On a large scale, rotary cutters are in use, but they are far beyond the reach of the amateur.

Contusion.

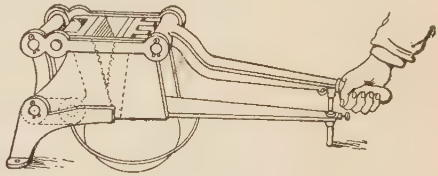
This is a bruising operation, which is very frequently resorted to to reduce a substance to particles, by striking a plurality of blows. A mortar and pestle is perhaps the most used apparatus for this purpose. Corrosive or caustic matter should never be pulverized in metallic mortars, and such substances as chlorate of potash should only be reduced

with the greatest possible care. Mortars are made of various materials, such as glass, wedgewood ware, wood and marble. Marble mortars are only recommended where the manufacture of toilet preparations, etc., is to be conducted on a considerable scale. Wooden mortars are useful in many cases. Boxwood mortars are the best wooden mortars. A sheepskin conical cover, with a hole in the center for the passage of the pestle, is recommended. It should be fastened around its rim and over its mouth with a string. Circular pasteboard and wooden covers are often substituted for the sheepskin cover. All substances of an organic nature should be previously dried, so as to afford greater facility for pulverization. A previous reduction of ores and coarse, hard substances into lumps, by concussion with a hammer upon an anvil, and of roots and like substances into slices or bits with a lever knife, are preliminary processes which greatly facilitate their pulverization. The substance to be struck upon the anvil can be wrapped in strong brown paper before crushing.

Silicious stones are pulverized much more readily after having been heated to redness in a crucible, and in that state thrust into cold water. This increased friability is occasioned by the unequal cooling of the mass. •Metals, alloys, and the like, which are pulverized with difficulty while cold, may be readily crushed when heated to redness. When it is required to reduce the substance into small frgaments only, it can be broken down by a succession of blows with the pestle. If the substance is very hard, the force of the arm should be added to the descending weight of the pestle, so as to impart power to the blow. A subsequent circular, grinding motion of the pestle, continued for a length of time, will further reduce these fragments to fine powder, and consequently this movement must be avoided when only a comminution is desired. The mortar should always rest on a sound foundation, and should be occasionally shaken during the operation of pounding, in order that the coarser particles which mount to the sides may be forced back to the center of the mortar so as to receive the full effect of the descending pestle. It should never be allowed to strike the sides of the mortar. If the substance is to be reduced to a fine powder, the process is greatly facilitated by operating upon only a small portion at a time, as the pestle is less liable to become clogged.

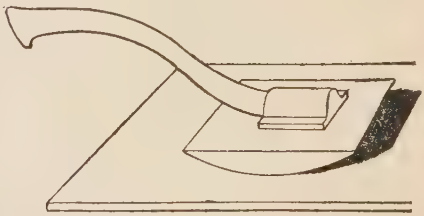
Grinding and Pulverizing.

These terms refer to the reduction of substances, by mechanical means, to coarse particles, this being usually referred to as grinding, while the word "pulverizing" is used to distinguish the reduction to fine particles. These processes are of great technical importance, and grinding mills are modified for the various purposes for which they are used,



Fine Rock Hand Crusher

and are manufactured by many concerns. Burr stones, roller mills, chaser mills, pebble mills, and mills having antagoniz-

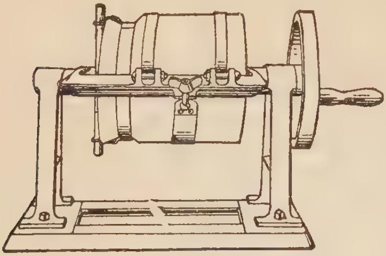


Bucking Board and Muller for Reducing Ores

ing grinder plates, and also various crushing and disintegrating mills, and machinery almost too numerous to mention. Hand mills, on the principle of the coffee mill, are of a great deal of use. The drug-mill type is recommended. For certain classes of grinding, the ordinary meat chopper will answer, such as for the cutting up of herbs.

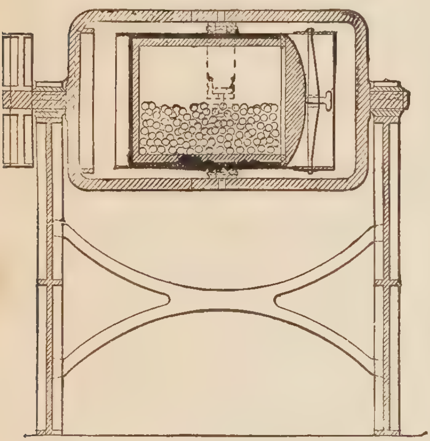
Grinding Mills.

Grinding mills may be purchased for all purposes. It is impossible to recommend any one mill which will be of universal application. If work is to be carried on on a large scale, an appropriate mill will prove an economy, even at first. The pebble mill is particularly recommended for general use. It consists of a porcelain jar, made of imported porcelain; these jars are impervious to the action of heat and such materials as ink,



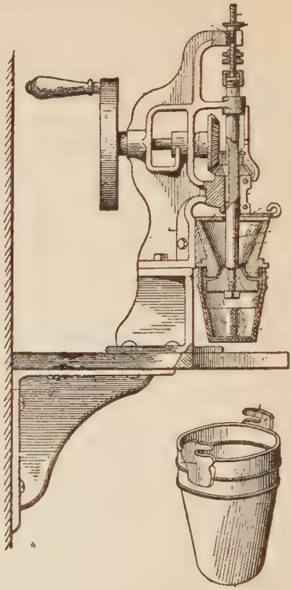
Abbe Porcelain Jar Mill

The effect is produced largely by friction: the sliding, tumbling and rolling inside of the mill of flinty pebbles or balls, which are mixed with the substances to be ground. The movement is caused by revolving the mill at a regulated speed. The type of mill which we illustrate will handle material up to 5 lb. in weight, and



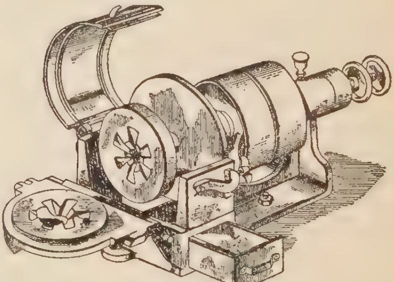
Interior of Jar Mill, Showing Porcelain Balls

is turned at about 60 revolutions per minute. It weighs about 120 lb. Those who are going to manufacture on a large scale will find a large variety of mills of this type. The action is very well shown by our section of the mill. The mills referred to are particularly adapted for hard substances. Articles of a vegetable origin may be ground in a drug mill, which may be had of any size. A spatula is absolutely essential; in fact,



Hand Power Sample Grinder

two or three of them will not come amiss. A steel spatula, and one of horn or rubber should be provided. Strange to say, the spatula is one of the most convenient implements to have in the kitchen.



Braun Type of Pulverizing Mill

Trituration.

This mode of manipulating with the pestle is applicable to those substances which are friable and fall to powder by being merely rubbed up by a circular or

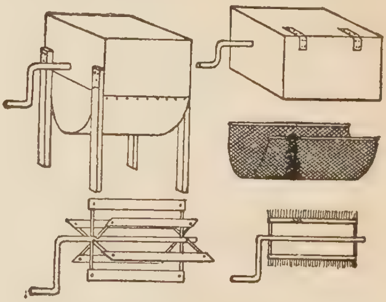
grinding motion of the pestle, and which would soften and become obstinate by being pounded. Chalk and the like, and most of the salts, are in the first category, the rosins and gum rosins in the second. The pestle is given a circular or spiral motion, accompanied by downward pressure. The operation is continued until pulverization is effected. Sand is added to facilitate the reduction of the rosins and similar substances, which cake under the pestle, only when they are intended for maceration or solution. Under other circumstances the medium would be an adulterant, on account of the impossibility of separating it. The process of trituration is also often performed with the aid of spatulas or flexible steel blades attached to handles, and is useful in the kitchen as in the laboratory. It is possible to get spatulas made of hard rubber for making preparations which contain corrosive substances.

Porphyrization.

This means of pulverization is only employed when it is desired to give the comminuted substance the greatest possible fineness, and takes its name from that of the material of which the vessels in which it is practiced were formerly made. A small porphyry mortar, hemispherical interiorly, or preferably a slab and miller, is the apparatus employed. Flint, and even glass, which are equally as hard as porphyry, form economical substitutes for that material. Porphyrization is usually effected by rubbing the coarse powder between a flat slab and muller until reduced to an impalpable state. The circular motion of the muller disperses the powder over the slab, rendering it frequently necessary to collect it together in the center with a spatula, so as to keep it uniformly under the action of the muller. When the substance under operation is unaffected by water it may be moistened with that liquid, which, by converting it into a paste, facilitates its reduction, and prevents any waste by the escape of dusty particles. The powdered paste is easily dried by being dropped in dots upon a porcelain plate exposed to warmth. Those matters which are soluble in, or affected by, water, must be porphyrized in a dry state.

Sifting.

The impossibility of reducing the whole of a substance at once to a uniform state of fineness by any of the preceding processes renders necessary an occasional separation, during the progress of pulverization, of the more comminuted portions from the grosser particles. This is effected by means of a sieve, of which there should be several in the laboratory. A wooden cylinder of about 4 in. depth, with an accompanying ring of the same materials, constitutes the frame, over which can be stretched a cloth of any required fineness. For coarser articles, fine brass wire is the best material for the cloth, but when the powder is to be impalpable, bolting cloth (raw silk), or gauze, is requisite. Sieves are also covered with haircloth, buckram, book muslin, and iron wire of different sized meshes, each of which has its appropriate application. The metallic sieves should have their cloths permanently fitted to them. For all the rest, two frames, as above described, one of much larger dimensions than the other, will serve, as it is only necessary to remove the ring when it is desired to substitute one kind of covering for another. The sieve of cloth, of graduated fineness, can be kept in some secure place, and withdrawn as wanted, and thus we have the economical means of possessing a full suite of sieves, from the metallic wire, through all the grades of fineness, up to the closest wrought bolting cloth. After the separation of the finer portions by the sieve, the coarser particles are again subjected to grinding and sieving as often as is necessary to convert the whole into the requisite state of uniform fineness. Where a more ex-



Home-made Sifter

tensive sifter is necessary, the one shown in our engraving can be used. Its construction will be readily seen by referring to the engraving. Horn scoops, or porcelain spoons or ladles, are the proper implements for transferring the contents of the mortar to the sieve. In some cases

a stiff pasteboard card, being more pliable, is a convenient substitute. The use of the hand for this purpose should always be avoided, as a slovenly practice. A platinum, horn or bone, or—less preferably—steel spatula, may be used to detach the particles adherent to the sides of the mortar. A round jarring motion will force through some of the coarser particles, and thus destroy the uniformity of the powder, and hence the common practice of tapping it frequently against the side of the mortar should be abandoned, unless the state of fineness is immaterial. Some substances, however, as magnesia, etc., which obstruct the pores of the cloth, must be forced through in this manner, and even if necessary by a circular motion of the fingers over the interior surface of the cloth. This manipulation frees the meshes of the cloth from obstructions, but it must be carefully done, otherwise the safety of the cloth will be endangered. A sieve is also useful for the admixture of powders of uniform fineness.

Levigation.

Is that mode of mechanical reduction which is practiced by first rubbing the substance into a smooth paste, and then separating the finer from the coarser portions by agitating the bruised matters with water. After a sufficient repose the grosser and heavier portions subside, leaving the lighter particles still suspended in the water. This water, after decantation, gives a second deposit of an increased state of tenuity. The third or fourth decantation yields the powder of impalpable fineness. The time of repose between the decantations, unless great impalpability is required, should be limited, and only long enough to allow the deposition of the heavier portions. The coarse precipitates are collected together a second time and as many more times as necessary, rubbed up as before, and treated with water until all the lighter portions have separated. This process applies only to substances unalterable by water. When uniformity of fineness is not at all important, one washing even suffices, and can be accomplished in the mortar without the use of glasses. Alternate poundings and washings will eventually reduce and remove the whole contents of the mortar. In washing over gold and other metallic ores, where only the heavier portions are to be reserved, the water may be allowed to flow directly into the mortar, which, being held in an inclined position, permits its exit, together with the fine dusty portions, which are kept in suspension by trituration with the pestle.

This process of levigation is founded upon the different specific gravities of the coarse and fine bruised matters, and is, therefore, not only applicable for the separation of the particles of homogeneous matters, but also of equally fine matters of unequal densities. In the latter case it takes the name of elutriation.

All minerals for analysis which have to undergo ignition with alkalies should be previously levigated, in order that decomposition may be complete; for if the powder is not uniform, the larger particles will escape decomposition.

Pulverization in this manner, by uniformly comminuting the particles, promotes their equal expansion and the escape of contained moisture, and thus prevents the decrepitation of substances when heated.

The deposited powder must always be dried, by exposure, previous to subjecting it to any other process.

Reduction by Granulation.

The reduction of metals to a pulverulent state is effected by fusing them in a crucible, and pouring the melted matter, from an elevation, in a thin stream, very gradually, into a bulk of cold water, which is, during the process, kept in constant agitation with a stirrer. The fineness of the resultant granules is proportional to the slowness with which the fused metal was poured into the water. It is more convenient to transfer the metal from the crucible into a ladle, and project it into the water from that more handy vessel, which enables a frequent change of the position of the descending stream, and thus prevents the formation of clots instead of smaller and more solid granules. The fusion of zinc for granulation must be in a covered crucible, otherwise it becomes oxidized while hot, and partially sublimes by exposure in an open vessel. Zinc may also be finely divided by being beaten, while hot, in a heated mortar. The process of fusing metals and then agitating the melted matter in a wooden box until cool, reduces them to a state of minute division, but at the same time promotes their oxidation. For general purposes, however, it is not objectionable, and the particles of charred wood with which it becomes mixed can be separated by elutriation. The sides of the box are generally well chalked, to prevent any adherence of the metal; this also is separable by elutriation.

Elutriation.

Elutriation is a process of obtaining substances in a very fine powder by the aid of water. The heavier particles fall to the bottom first, and the lighter particles follow. Advantage may be taken of this principle in constructing an elutriating apparatus, which may consist of a large iron pan having 4 or 5 openings and valves, so that a portion of the liquid can be drawn off containing finer or coarser particles. Elutriation has been aptly called water sifting. It is an extremely economical process, especially when carried on on a large scale.

Pulverization by Intermediation.

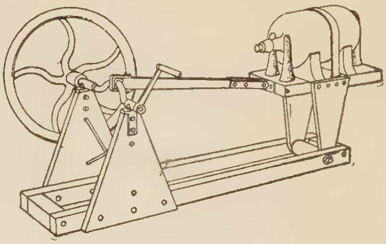
This mode is both mechanical and chemical, and applies particularly to the noble metals, in foil, which are difficult of pulverization. Honey, sugar, salts, etc., are the most usual media. By binding the particles together it assists their minute division, and prevents their escape from the mortar. The addition of boiling water solves out the medium without action upon the metallic powder, which then only requires to be thrown upon a filter and dried. Phosphorus may be finely divided by fusing it with alcohol over a water bath and shaking the contents of the flask until thoroughly cooled. The phosphorus subsides at the bottom in pulverulent form. Camphor, which is obstinate under the pestle, readily yields to its power when mixed with a few drops of alcohol or ether to destroy its elasticity.

II

SOLUTION AND EXTRACTION

Solution.

When a substance added to a liquid is wholly or partially taken up by that liquid it is said to be soluble therein. The liquid employed is termed the solvent, and its combination with the dissolved particles a solution; and if the liquid has exerted its solvent power to the fullest extent, then the solution which it forms is said to be saturated, because it can hold no more. The variable degree of solubility in different liquids serves as a distinctive characteristic of bodies, particularly those which are solid. Solution is either wholly mechanical, or else chemico-mechanical. In the first case it is a molecular division of a body, or, in other words, a diffusion of its particles in an appropriate liquid without any alteration of its original properties, save as to form and cohesion. Thus, for example, an aqueous solution of sugar or salt yields the whole of its charge by evaporation, and one of sulphate of lime by addition of alcohol, in which it is insoluble. Ethe-



Agitator for Liquids

real or spirituous solutions deposit their dissolved matter by distillation or crystallization; and some other kinds, that of gutta percha, in chloroform, for instance, by precipitation with ether or alcohol. When the dissolved particles are thus recoverable again in an unaltered state, chemically considered, their solution may be styled *simple.*

In the second case, chemico-mechanical solution, in contradistinction to that which is purely mechanical, is a process requiring the modification of a body by chemical action previous to its solution. Thus, for example, copper, iron, or any other base or acid, insoluble in the ordinary solvents, may be readily taken up by liquid acids or bases. But the liquid holds in solution a newly formed body entirely dissimilar to the original substance in properties, as appears when it is separated. In this, therefore, consists the difference between a simple, or mechanical, and a chemico-mechanical solution. As examples of this latter, iron may be dissolved in dilute sulphuric acid, but in the act is transformed into copperas; alkalies are taken up by acids, but become altered to salts; and oil, in being dissolved by potassa solution, is changed into soap. Hence it is that the chemical reaction is a preliminary step requisite to promote simple solution. The point of saturation in chemical solution is that at which the two bodies, invariably of opposite properties, have combined in proportions adequate to neutralization.

Solution is one of the most important processes in chemistry; it not only facilitates chemical reaction, but allows the separation of soluble from insoluble bodies, or parts of the same, and consequent-

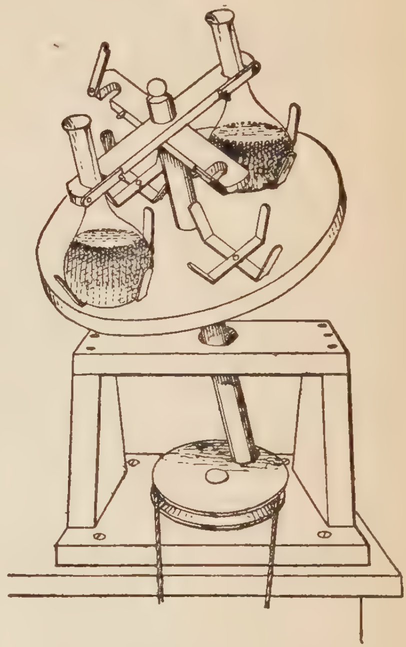
ly the purification of the solution by subsequent filtration, evaporation and crystallization.

As regards the power of dissolving the greatest number of substances, water is the first in the rank of simple solvents, alcohol the next, and ether third. Then follow spirits of turpentine, pyroxylic spirit, the volatile and fixed oils, chloroform, and a host of other liquids suitable to particular substances. Of the alkalies, aqua ammonia, or potassa, are most used; the former preferably because of its volatility, and that of most of its salts. All of the common acids are employed, though some few only are of general application, such as the muriatic, nitric, sulphuric, acetic and tartaric.

A very convenient way of testing the solubility of a substance is by means of a test tube. If solid, a small portion, in powder, is to be introduced, and covered with distilled water, or the solvent to be used, and repeatedly agitated by the hand, the forefinger closing the mouth to prevent the escape of particles. If the matter is wholly soluble, there will be no deposit at the bottom of the tube; if partially soluble, the deposit will have decreased in bulk; if totally insoluble, it will occupy the same space as at first. To determine as to the two latter results, a minute portion of the supernatant liquid is decanted and evaporated in a small platinum spoon, or strip of window glass, over a spirit lamp; if a residue remains, it indicates that matter has been taken up. When heat is required, the lamp affords a convenient means of application. The procedure in such cases is the same as that above indicated.

1.—There are certain conditions which greatly facilitate the solution of substances: First, comminution, which increases the extent of surface; second, agitation, which promotes the frequent contact of all parts of the surface with fresh portions of solvents; third, the freedom from impurity of both the solvent and the body to be dissolved; fourth, it is also influenced by the quantity and state of dilution of the solvent; fifth, by the temperature; sixth, by the mode in which the process is conducted.

2.—Agitation is effected by stirring with glass rods when the containing vessel is open at the top. The rod should be rounded at the end over the blowpipe flame, and to prevent its rolling from the table or top of the vessel upon which it should be placed, may be square, instead of cylindrical, as usual. A very convenient and effective mode of bringing all portions of the liquid successively in contact with the substance to be dissolved is to place the latter in a colandered diaphragm suspended beneath the surface of the liquid. The first stratum of liquid, in becoming saturated, increases its density, and consequently descends, and displaces a lower and fresher portion, which, being in the same way surcharged in its turn, gives way to successive strata, and so the operation continues until the whole of the matter, or so much as can be, is taken up. This mode keeps the substance in constant contact with new portions of liquid, and is, in fact, a kind of *displacement* process. When flasks or bottles are used, the same effect may be produced by repeated shaking. Trituration in a mortar, and alternate decantation and fresh additions of the solvent, greatly facilitate the solution of solid substances.



Power Mixer for Liquids

3.—The purity of the solvent is an important consideration, for if it contains foreign matters they may impart a dissolving power which is not inherent in

the pure liquid, or diminish that already possessed by it.

4.—In regard to the quantity and state of dilution of a solvent, it must be remembered that some substances require more of it than others for their solution, and that it should be in a greater degree of dilution. Therefore, in examining the solubility of a body, always commence with small quantities, and increase both quantity and strength gradually as may be required.

5.—Temperature exerts a considerable influence in the solution of bodies, and though in a few instances, as in the solution of lime, magnesia and anhydrous sulphate of soda in water, its elevation impairs the power of the solvent, yet, as an almost universal rule, it facilitates its action. The temperature must be adapted to the nature of the solvent and the substance to be dissolved, and of the solution formed.

It may be as well to mention that the caloric rendered latent at the moment of the liquefaction of a solid, which is being dissolved in a liquid, causes a decrease of temperature. Solution in volatile liquids should be, in most cases, performed in the cold, and, when of small quantities, in narrow-necked flasks. If heat is required, especially when the vapors are inflammable, a retort or covered still must be used; and if the distillate is valuable, a recipient may be annexed to receive as much as comes over.

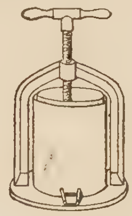
The mode of effecting solution varies with the substance under process: Maceration, decoction, infusion, digestion, boiling and displacement have each and all appropriate application.

In ordinary solution, the solid should be added in portions, and sufficient interval allowed for the solution of those in the liquid before fresh are added. In case of foaming or effervescence, an additional amount of fluid will produce a calm.

Some volatile substances which are insoluble in water under ordinary circumstances are taken up by it in the state of vapor. For this purpose both should be distilled together.

When solutions emitting corrosive or disagreeable fumes are being made in open vessels the operation should be conducted under a hood the barrel of which connects with the chimney flue, so as to insure their exit. The containing vessels should be those which resist the action of heat, acid, alkalies and corrosive liquids.

For making saturated solutions of most substances, ebullition is necessary. For this purpose the solid must be boiled with the solvent until the latter, on cooling, deposits some of its charge. The cooled solution is then to be filtered



Hand Press

Expression.

By expression we are to understand the process of separating solids from liquids by means of force. Presses are usually used for expression, and are divided into screw presses, lever presses, hydraulic presses, etc. The ordinary screw press shown in our engraving is of great use. The ordinary meat chopper, with a knife in one piece, and costing $1.50, is a valuable aid to expression. Horizontal screw presses of the same general appearance express as well as cut.

Maceration.

The soaking or steeping of a substance in a liquid, at the ordinary temperature, is termed maceration. It is almost exclusively applicable to organic substances, being most frequently resorted to as a means of hastening and facilitating the after solution of the extractive parts of hard, compact or impervious wood, roots, stems and leaves, by the more active methods of *displacement* and *ebullition*. It is employed when the soluble principles are alterable by heat, and is also made use of to effect the solution of a substance containing several principles, the solubility of which varies with the temperature applied, as it leaves those which are not taken up in the cold to be acted upon by the aid of heat. Thus, for example, in the treatment of most vegetable substances, starch, which is generally present, and is only soluble at the boiling point of water, will remain untouched, while all other principles soluble without heat can be separated from it.

The mode of performing the process is merely to place the solvent and the substance to be dissolved together in a

vessel, and allow them to remain a longer or shorter time, according to the nature of the substance. For ordinary purposes, a loosely covered pan of blue stoneware is very convenient. In delicate operations, a beaker glass, or solution jar, is more appropriate. When the solvent is volatile, a wide-mouthed, stoppered bottle may be used.

Infusion.

This process is likewise applicable almost solely to organic substances. Instead, however, of the solid remaining in contact for a length of time with the solvent, the latter is first heated to boiling and then poured upon the former.

This mode is used for the exhaustion of flowers, leaves, roots, seeds, and other substances of delicate texture, which are easily penetrable and readily yield their soluble matters; and especially for the purpose of extracting volatile ingredients. The heat applied to the solvent increases its energy; but as the material is only in contact for a limited time, the interval between the commencement and completion of the operation is not sufficient to affect the material or solution, even though one or more of its components are alterable by heat.

Decoction.

This mode of solution, which is so important to the pharmaceutist, is chiefly employed for the purpose of exhausting those vegetable substances the components of which will not readily yield to other means. It is merely an extension of the last process, and consists in that contact of the material to be dissolved with a hot solvent in a covered vessel, which is continued until all soluble matter is taken up. Most volatile matters are epelled by decoction, but those which are insoluble, save by prolonged action of heat, are dissolved or suspended, as it were, by favor of other principles present. Decoction is only used with liquid solvents which are not decomposable by heat.

In all of the preceding processes, as well also in others in which solid vegetable matter is subjected to the solvent action of liquids, the colandered ladle of tinned wire is most useful for transferring the residue to the press, for removal of any retained liquid.

Digestion.

This mode of solution differs from maceration in requiring the assistance of heat, and consists in exposing a body to the prolonged action of a liquid in a covered vessel, at any temperature between 90° F. and several degrees less than the boiling point of the solvent. The method of heating varies with circumstances, and can be by a gentle fire, or by the sand, steam, water or saline bath, as the nature of the operation requires.

In analysis, glass or platinum vessels are used, but in less important operations those of other materials are more convenient and economical.

A very important advantage of digestion is that it allows the perfect solution of all soluble portions of a substance without modifying the nature of the solvent. It is especially useful for the decomposition of ores, minerals, and other substances with difficulty acted upon by acids or other solvents, and also for effecting the synthesis of compounds requiring a long continued heat. Moreover, it is very available in preparing alcoholic and aqueous solutions, medicinal oils and other pharmaceutical products.

Evaporating Dishes.

Special evaporating dishes of porcelain, glass, or enameled steel, can be purchased of all dealers in supplies, and are specially recommended. Broad, shallow vessels should be usually selected. If glass evaporating dishes are to be used, they should be heated in a sand bath. The evaporation is aided by stirring; glass rods, or porcelain or wood stirrers, should be used. If the reader is going to use large quantities of the same materials, various means of stirring artificially will present themselves. Evaporation of many substances should be carried on under a hood, which may be of sheet iron or galvanized iron, like the hood over a blacksmith's forge, or the work may be carried on in an evaporating chamber, which may be likened to a closet with the lower portion boarded up so that the floor of the closet is of a convenient height to be reached with the hands. There should be a closed window in the closet, which should be well ventilated to the outside by galvanized iron or asphaltum painted ventilating tight. All the arrangements for gas, etc., should be at the front of the evaporating chamber, so that it will not be necessary to reach over hot plates, etc.

Steam Baths.

Steam is very largely used in the arts for maintaining a steam bath. The steam may or may not be under pressure. Where steam without pressure is used, either a

steam jacket is constructed, or the live steam may be conducted directly into the top. A steam distributor can be readily constructed with the aid of pipe or elbow Ts, etc., and this tends to distribute the heating more equally, and serves to mix the ingredients which are being heated. If considerable operations are to be carried on, the use of steam under pressure is recommended for many purposes. Superheated steam, of course, raises the temperature considerably; thus, if steam at the ordinary atmospheric temperature is to be increased, a temperature of 240° may be obtained by a pressure of 40 lb. to the square inch, while with a pressure of 80 lb. to the square inch a temperature of 312° can be obtained. It is possible to build a water bath with a jacket in which steam at high pressure is gnerated directly in the water jacket.

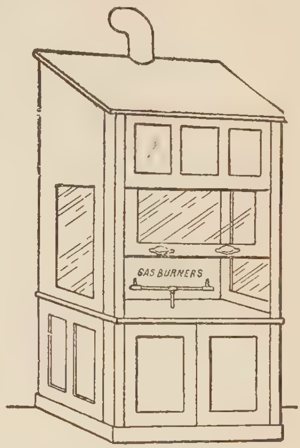
Attemperating Baths.

There are many substances which have to be treated moderately to heat, so as to prevent the decomposition or destruction of the substance which is being treated. This is especially the case with medical preparations. Various attemperating baths have been devised, many of which are extremely ingenious, and are fully illustrated in the catalogues of dealers in chemical apparatus. The sand bath is one of the best-known means of producing an even heat without burning. It can be readily made by putting sand in a pan over the naked fire and putting next in porcelain or other vessels as it becomes necessary. Oil and paraffine baths are used for certain purposes, as are also glycerin baths. The water bath is perhaps the most widely distributed and best-known means of regulating the heat which is applied to substances. The water bath may be extemporized, or the special baths furnished by dealers in chemicals may be used, which are more satisfactory, being specially adapted to the purpose. Salt-water baths are also largely used. The action of salt in the water is to raise the boiling point.

DRYING AND DESICCATING

Mechanical Methods.

Foremost among mechanical appliances for this purpose ranks the centrifugal machine, or hydro extractor. In principle, this apparatus consists of an upright drum, which can be made to revolve with great velocity on a vertical axle. The drum may have its sides constructed of sheet metal, perforated with a multitude of fine holes, of wire gauze properly supported, or of basket work, according to the nature of the substances to be treated. The drum, being charged with material, is set in quick rotation. The water present is thus expelled through the perforated sides, in the form of a fine shower. This



Hood For Chemical Work

process is exceedingly well adapted for removing the greater part of the moisture from cloth, yarn, unspun wool, etc.; also from crystalline and granular substances. It is not so well adapted for drying wet powders, pastes, etc., since in such cases a very considerable proportion of the solid matter is projected away along with the liquid, so the holes may get choked up. Thus it has not hitherto been found satisfactory for drying sewage mud. Its use requires, further, special modifications where the liquid to be got rid of is not pure water, but holds useful or hurtful matters in solution. A recent very simple improvement has considerably extended the use of the hydro extractor. The materials, instead of being put into the drum loose, are inclosed in bags of some suitable material, thus preventing the dispersion of the solids. This method has been very successfully adopted with butter. It must, however, be remembered that no substance, especially if of organic nature, can be rendered absolutely dry by the use of the hydro extractor.

Another mechanical agency for desiccation is the press, more especially that device known as the filter press, which

has proved itself invaluable for separating solids from fluids when the latter largely predominate. This apparatus contains a number of cells, each consisting of a couple of cast-iron plates, lined, when in use, with suitable cloths. The inner surface of each plate shows a number of ridges. The liquid paste is forced by a pump or press into each cell, through an aperture, and the water escapes through the cloth, and trickles down between the grooves formed of the ridges to the pipe at the bottom.

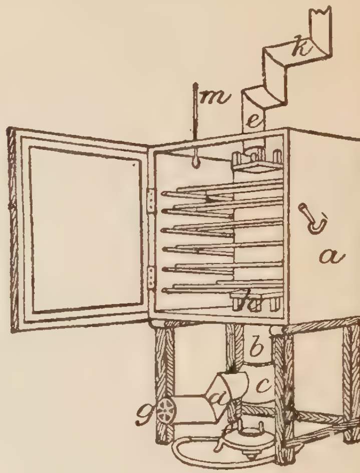
The filter press, like the centrifugal machine, only expels a part of the water in mud, etc.; thus, if a sewage mud contains at the outset 90 to 95% of moisture, it may be reduced by the filter press down to 50 to 60%, according to the time during which the pressure is maintained. It is only in a few cases that hydraulic presses, screw presses, etc., can be employed for desiccation.

Small Hot-Air Baths or Closets for Laboratory and Other Purposes.

(*a*) The ordinary steam or hot-air chambers for laboratory use, although meeting the most of the requirements for which they are designed, have the disadvantage of being more adapted for experimental than manufacturing purposes. The want of a cheap and convenient apparatus induced Maben to bring under notice a design, due to Hyslop, one of his apprentices, who intended it for drying photographic gelatine plates; but, by slight modifications of the interior, it is perfectly adapted for the purposes of the laboratory.

The chamber consists of a strong wooden box, *a*, 18 in. high by 18 in. wide, and 14 in. deep. To the front a door is attached, hinged in this instance, but a vertical sliding movement would be more convenient. To two sides of the box are fixed wooden supports, which serve to receive teak spars for supporting drying trays or evaporating dishes. The bottom of the box has a perforation of 3 in. diameter, into which a zinc cylinder, *b*, is securely fitted, and to this is soldered the upper end of a copper cone, *c*, with a flat bottom, while into this latter a bent tube of 2½ in. diameter and 9 in. total length is securely inserted in the manner shown. A corresponding perforation is made in the top for receiving a tube to answer the purposes of a chimney.

Using a Bunsen burner or a spirit lamp as the source of heat, the flame is directed to the bottom of the cone, *c*, with the result that the heated air ascends into the chamber, being diffused by means of a dispersion board, *h*, about 4 in. square, which is placed over the orifice. At the end of the tube, *d*, is fitted a "hit-and-miss" regulator, *g*, which consists of a series of triangle-shaped holes, with a re-



Laboratory Drying Closet

volving disc behind, so that the size of the apertures can be increased or diminished, thus enabling the amount of air entering to be under partial control. The highest temperature to which the air in the chamber has been raised is 180° F. (82° C.) which is sufficiently high for most operations. If a uniform temperature of say 100° F. (38° C.) be required, the admission of air must be regulated accordingly by means of the regulator, *g*, accuracy being insured by the insertion of a thermometer, *m*, into a perforated cork fitted into a ½-in. aperture on the top of the chamber. By this means there is no difficulty in keeping within 2½° less or more of the desired temperature.

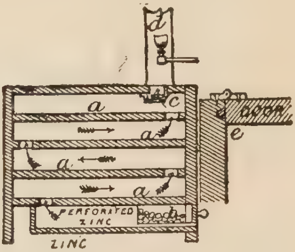
If a rapid current of warm air is desired, this can be had by placing an angular tube, *k*, on the top of the chimney, *e*; by heating the angle of the tube a draught is quickly created.

It is desirable in some cases to filter the admitted air; this can be done by stretching a piece of lint or other suitable material between the regulator, *g*, and the tube, *d*, by which means dust particles are effectually excluded.

The metallic parts of the apparatus being made to screw off and on, they can be detached at will, so that we can thus have a series of wooden chambers suited to different purposes. In this instance, the chamber being intended for drying gelatine plates, it was of course constructed so that the light would effectually shut out, but it is obvious that a small glass window would add greatly to its value for most other purposes. The advantages of this chamber are its simplicity, its perfect security against overheating, and its small cost—it can be made for a few shillings. It is light and easily handled, and is always ready for work, a current of pure hot air being obtained in a very few minutes after the application of the Bunsen flame. It is specially adaptable in the preparation of granular and scale compounds, for drying precipitates, hardening pills previous to coating, and in other operations requiring a current of hot air.

(*b*) A writer describes his drying closet as being made of teak 1 in. thick, with light-tight door in front; the ends project beyond the bottom to form legs; the top and bottom are both double (4 in. apart), and the air enters through a slit 3 in. wide, and reaching right across the box. This slit is at one end, and the air has then to pass along the double bottom to the other end, where it gets into the box through a similar slit, thus keeping out the light; and it gets out at top in a similar way. Over the exit at top is fitted a tin or copper chimney 3 ft. high, in which burns a Silber lamp, giving a good draught, and drawing a large quantity of air through. Inside the box are brackets (each having a leveling screw through it, with the point upward), projecting from the ends, on which are laid plate-glass shelves cut the width of the box, but 3 in. shorter, so that when the shelves are in place, if one is pushed close to the right end of the box and the next to the left, and so on, the air has to pass backwards and forwards over the plates. His box has 3 shelves, 13 in. wide and 32 in. long, and will dry 6 photographic plates 15 in. by 12 in., or, of course, anything less that will lie in the same space. Some have an arrangement for drying and warming the air before it enters the box; but this sometimes induces blisters and frilling. Shelves should be far enough apart to get the hand in easily, say 6 in.

Our next engraving shows a sectional view of another form of photographic drying box. *a* are shelves on which to put plates. In the drawer, *b*, are placed some lumps of calcium chloride. This absorbs moisture very rapidly, and the air in passing through it is thoroughly dried. In the flue, *d*, is a small gas burner, and below is a light trap, *c*, made of tin. The gas jet is for the purpose of causing an extra current of air to pass over the plates. It is better to confine the plates as much as possible to the 2 middle shelves, as there they are sure to be safe. At *e* is a sketch showing how

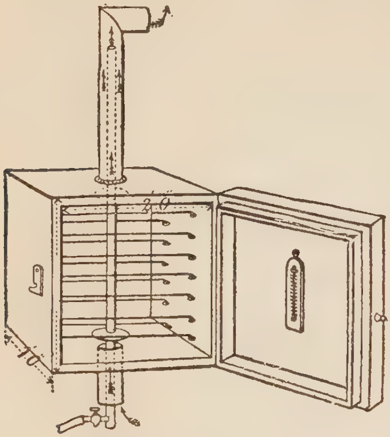


Photographic Drying Box.

the door of the box should be rebated into the side.

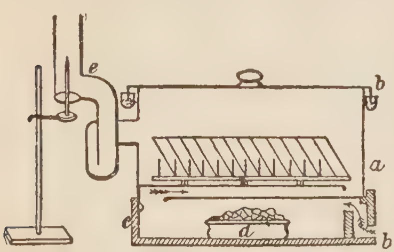
(*c*) England's drying closet is simply a light-proof box with wires stretched across the interior to suport the articles to be dried; *e.g.*, photographic plates. Through the center runs a 1-in. gas pipe, open at both ends, with a small gas jet burning inside at the lower end. At the top and bottom of the box 2 draught holes are cut, to which a tin tubing of about 3 in. diameter is attached. The gas tube gets warmed with a very small jet of gas burning in it, a mere pin-hole being sufficient exit for the gas. This warms the air in contact with the tin tube, and also slightly the air inside the cupboard. The consequence is, that a current of slightly warm air is set up, and circulates among the plates while supported on the wires, and the drying of the films takes place rapidly. Some 5 to 6 hours is a sufficient time in which to dry the plates, while without the gas jet it would take 24 hours or more. In the inside of the cupboard, and near the top and bottom, are placed 2 cardboard discs to stop the possibility of any stray light entering, and as the whole affair is placed in the dark room, the chances of any such access even without it would be small. Inside the cupboard door is a thermometer, and the jet is regulated so that a temperature of about 70° F. is indicated—80° would do no harm to the plates; beyond that tem-

perature it might not be safe to go. The small gas jet used is the same as seen in tobacconists' shops; the hole in the end is plugged up, and a very small hole drilled at the side.



England's Drying Closet.

(*d*) A photographer adopted a large zinc case with a lid of the same material. He cut a long opening at one end of the bottom, and had another bottom soldered inside with an opening at the opposite end. He then had a Russian iron chimney fastened on one of the sides, and fitted this with a gas flame placed as shown, so that it might produce the necessary current of air. To make the cover fit air and light-tight was rather more difficult. This, however, he managed in the following manner. He had a rim soldered



Calcium Chloride Drying Box.

all round in the shape of a gutter, the edge of the lid sinking into the bottom of the gutter, and then filled the latter with small shot, and thus obtained a most perfect closure. This box has been in use ever since, and, with the addition of a wooden tray, and of an iron vessel full of calcium chloride, has done very good service. In the figure, *a* is the zinc case; *b*, gutter filled with shot; *c*, wooden tray; *d*, calcium chloride vessel; *e*, Russian chimney.

(*e*) The usual form of hot-air baths used in laboratories are, almost without exception, affected by drawbacks, particularly the following:

1.—Either the temperature in the upper and lower parts is different; or

2.—The temperature differs with the duration of heating; or

3.—It can only be raised to a moderate degree; or

4.—Finally, it can be kept up only by a relatively large consumption of gas.

Meyer proposes to remove these defects in the following manner:

Equality of temperature may be attained by applying the heat at the side—never below—and by taking care that the flame never comes in actual contact with the metal. The space to be heated is to be surrounded with the hot products of combustion of the flame mixed only with the smallest possible excess of air, in such a manner that a triple layer of heated gases, proceeding from without in-

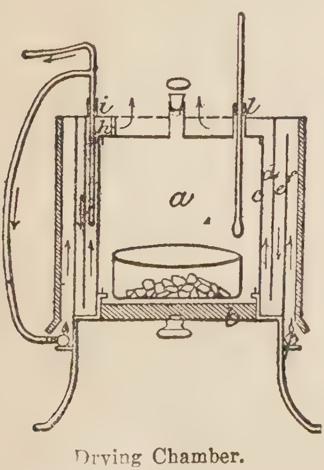
Fig. *a*

Fig. *b*

ward, surrounds the inner mantle. Besides, the outer, or hottest layer, must be protected from too rapid cooling by applying a suitable coating of bad conductibility for heat.

Equality of temperature for any length of time may be best attained by a regulator constructed on the principle of Andrea's, which contains, in a small, confined space a small quantity of a liquid having a boiling point a trifle below the degree of temperature to be maintained. The author prefers the modified form suggested by Kemp, and improved by Bunsen, which is wholly constructed of glass except the lower end of the gas tube, this being made of perforated sheet platinum.

In order to fill it, the gas tube, *a*, Fig. *a*, is temporarily replaced by a tube, *b*, drawn out at both ends and reaching down into the reservoir of the regulator (top of Fig. *b*). The lateral branch, *c*, is now connected with the vacuum pump, the whole inverted (as in Fig. *b*), and contracted end dipped, first into the liquid to be used as regulator, and then into mercury, until the chamber is almost, but not quite, full. The apparatus is now turned over, a little more mercury poured in, and the gas tube, *c*, is inserted. When using the apparatus, the gas tube is first drawn upwards, and, when the proper temperature has been reached, pushed down into the mercury, until the supply of gas is reduced to a minimum. By cautious adjustment, it is easy to find the position at which the tension of the vapor developed in the tube raises the column

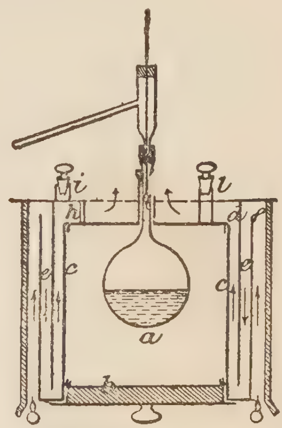


Drying Chamber.

of mercury sufficiently to just close the orifice of the tube, *c*, at the proper temperature. As the air bath cools off very slowly, but heats up rapidly, it is of advantage to adjust the regulator to a slightly lower temperature than actually required.

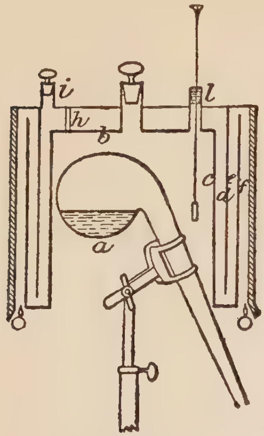
It is best to have a series of such regulators, charged with substances, the boiling points of which are about 30° C. apart, and to keep them in a proper receptacle for use. Suitable substances are, for water baths: ethyl chloride, ether, carbon disulphide, mixtures of ether and alcohol, benzole; for air baths: water, toluol, xylol or amylic alcohol, cymol or oil of turpentine, aniline or phenol, naphthaline, diphenyle or diphenylmathane, diphenlyamine, and perhaps also anthracene. It is not at all necessary to use these in a pure state, particularly those which are solid at ordinary temperature, since they melt more easily when impure. Only very little of solid substances should be introduced, for the excess distils off, and may clog up the gas tube.

The annexed engraving shows an approved air bath.



Drying Air Chamber Arranged for Distillation.

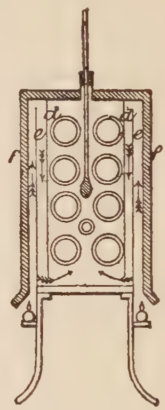
It consists of 4 concentric walls of sheet copper, 2 of which are attached to the upper plate, and the others to the bottom plate. It can be arranged for the dry distillation of substances which should not be heated beyond a certain point (for instance, citric acid in the preparation of aconitic acid, etc.).



Drying Chamber Arranged for Dry Distillation.

The innermost cylinder* surrounds the space, *a*, to be heated, which is closed from below by a double bottom, *b*, fastened by a bayonet-clamp. The upper cover also double (the 2 walls being kept parallel by inner supports, of which one is shown at *h*), has 2 tubulures, one, *l*, for the insertion of a thermometer, another, *i*, for the regulator, and another for the escape of the heated vapors. To this cover the 2 cylinders, *d* and *f*, are attached, while *e* and *c* are soldered to the bottom piece, which is also provided with 3 legs. The heating is done by a brass ring attached to the legs, with a supply of gas controlled by the regulator, *i*. The ring has holes of 2 to 3 mm. bore in intervals of 3 cm. The little flames thus produced burn quietly and may easily be regulated. With the same amount of gas which is furnished by a gas cock supplying an ordinary Bunsen's burner, the space in a (= about 5 l.) may readily be heated to 300° C. and over, even when it is not closed below. But in order to obtain this result, the intervals between the several cylinders, in which the products of combustion circulate, must not exceed 10 mm. Besides, the outer cylinder, *f*, must be protected with a non-radiating cover. The best, for this purpose, is a layer of asbestos (in sheet), to be applied so as to leave a little space between it and cylinder *f*, which space is to be filled out with silicious earth ("kieselguhr") or mineral wool.

If tubes are to be heated, the modification shown herewith may be used. It is also here of importance that the channels through which the warm air circulates are very narrow, scarcely 1 cm. apart. The 8 iron tubes pass through the narrow walls, which latter are not double but covered with little flaps hinging upwards (one corresponding to each tube), as closely as possible fitting to the surface of the outer cylinder, but remaining slightly distant from the ends of the tubes. In case a glass tube (inserted in one of the iron tubes, for being heated) should explode, its fragments are caught by the loosely hanging flaps. Between the iron tubes, a Babo's regulator may be inserted.

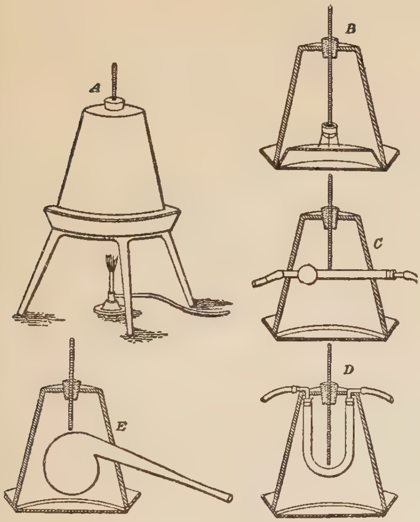


Drying Chamber Arranged for Tubes.

For special uses the above forms of air baths may be still further modified. It is, however, of importance to remember that the heated gases should surround the space to be heated in a triple layer; that the hottest layer should be near the outside, and that the intervals between the walls should admit as little excess of air as possible. The gases escaping above must have the property of extinguishing a glowing splinter of wood.

(f) The air bath ordinarily used in chemical laboratories for drying precipitates, for making determinations of water by loss, and for similar purposes, is usually a rather expensive piece of apparatus. The iron or copper closet, with its door, tubulure for thermometer, shelves, stand,

*The air chambers illustrated above are not square, but round. The illustrations represent a vertical section through the center.



Air Baths.

etc., works no more satisfactorily because of its somewhat elaborate or difficult construction. In our engravings are shown a simple substitute for this apparatus, that as regards simplicity cannot well be excelled, while its other good features certainly operate to commend it. It consists of an inverted flower pot sustained upon an ordinary tin pan or sand bath, the whole being carried by a tripod or retort stand. The aperture at the top serves to receive a perforated cork through which a thermometer is passed. An ordinary Bunsen burner is used to heat it. As the sand bath directly over the burner becomes very hot it is advisable to invert a second smaller sand bath within the first as shown in B. This prevents too direct a radiation of heat from the hot metal. Upon this the little stand or bent triangle supporting the crucible or watch glass containing the substance to be heated may be placed. The thermometer should be thrust down through the cork until its bulb is near the substance to be dried, so as to obtain a correct indication of the temperature at that point. The entire arrangement is shown in external view in A.

To place the vessel in it or to remove one, the flower pot is lifted off the sand baths. It will be observed that its porous nature provides a species of ventilation, while its composition assures it against corrosion. It even protects the plates below to a considerable extent, as drops of water or other fluid cannot run down its sides as it cools.

But convenient as it is in the rôle of air bath for simple drying operations, it will be found more so where drying tubes or retorts have to be manipulated at constant temperature. The flower pot can be perforated at any place, and holes of any size or shape can be drilled and cut through it with an old knife, file, or other implement. Thus in C it is shown in use for drying a substance at constant temperature in a straight drying tube. The holes to receive this tube can be drilled in a few minutes. The arrangement as shown is of the simplest kind, but if the usual bath was used, it would require a special tubulation to be introduced or contrived for the tube to pass through. Flower pots cost so little that there need be no hesitation in preparing them for special uses.

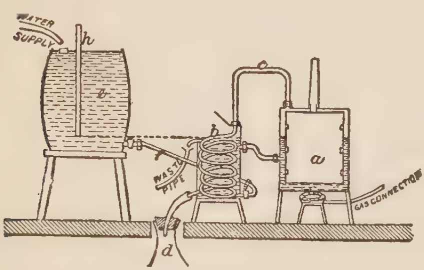
In D a U tube is shown as being heated, while in E a retort occupies the bath, and is in use for fractional distillation or other operation requiring a constant temperature. In all cases it is better to use the second bath inverted within the chamber. It conduces greatly to the maintenance of an even temperature throughout the whole space. A hint may also be taken from the heavy drying plate formerly perhaps more used than at present. If for the light metal pans a heavy plate of ½ in. or more in thickness is substituted, the temperature will not be subject to as rapid variations, and less difficulty will be experienced in keeping a constant temperature. The tray furnished with the next large size of pot may be used instead of the sand bath upon which to rest the inverted flower pot. This gives an absolutely non-corrodible construction.

When the bath is in use for drying substances, its top, which is at a rather low heat, affords an excellent place of drying precipitates wrapt in their filter papers. It acts in two ways. It is generally just hot enough to dry them with reasonable quickness without danger of spurting, and it also acts by capillarity to absorb the water directly. It represents in the last respect the porous tile or blotting paper—appliances too little appreciated by chemists here. It must be remembered that the drying of a precipitate by evaporation leaves all the impurities of the wash water concentrated therein, while capillary absorption removes a great part of both

wash water and its impurities, thus conducing to the accuracy of the work.

Water-heated Air Baths and Ovens.

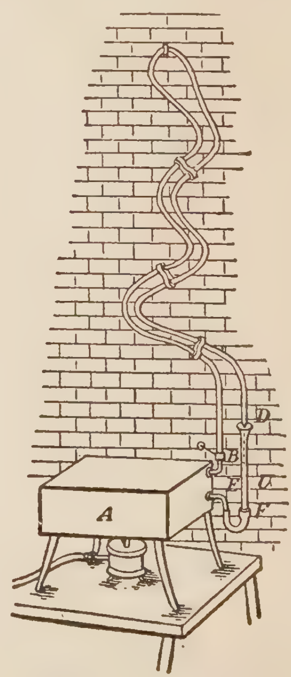
(*a*) The accompanying sketch of a combined steam oven and distilled water apparatus, so arranged as to be left to itself for a long period of time without the risk of the boiler going dry, may perhaps be of interest to many, and a few words only are necessary to describe the working. The steam oven, *a*, is of the ordinary construction, but is fitted at the side with a tube connecting it with the condenser, *b*. Heat is applied to *a* by means of a radial burner, connected with the gas supply by metallic tubing; the steam generated circulates around the drying chamber, escapes through the copper tube, *c*, thence through block-tin worm, and falls as distilled water in the receiver, *d*. The cistern, *e*, fitted with a Mariotte's tube, holds cold water, which falls through the tube, *f*, enters the condenser, where it rises slowly, absorbing heat from the condensing worm, until it reaches the tube leading to the boiler at a high temperature. For a cistern, an 18-gal. ale cask, supported on a stool, has been found to answer admirably, having the advantage of holding sufficient water on the top to secure the 2 corks being airtight. By a suitable adjustment of the Mariotte's tube, *h*, the rate of flow of the water can be so regulated that the level of water in the condenser is constant, or, if desired, allowed to drop slowly into the waste pipe, while the water evaporated from *a* is renewed by water



Steam Oven and Distilled Water Apparatus.

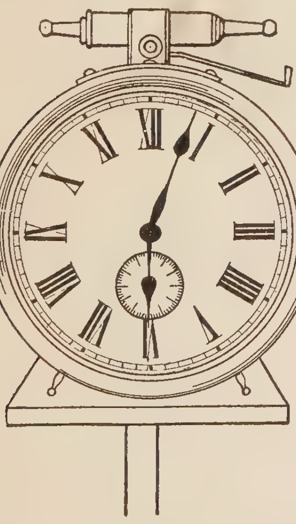
already near boiling. In practice it has been found necessary to allow the water to waste at the rate of about 2 drops per minute, the 18 gal. lasting for over 72 hours, during which time 10 to 11 gal. of distilled water are collected. When this apparatus was first fitted up in the laboratory, it was intended to have connected the condenser directly with the town water supply, but as the waterworks authorities would sanction no such connection, we had recourse to the cistern, with the satisfactory result that we are in this respect quite independent of the caprice of the waterworks turncock. The several connections are made by union joints, to allow the apparatus to be taken to pieces and the boiler freed from scale. The whole apparatus may be supported upon a strong shelf, which should be protected from the heat of the burner by means of slates or asbestos millboard. With this arrangement, bulky precipitates may be allowed to remain in the steam oven all night and found ready for further treatment next morning.

(*b*) In the annexed engraving is shown a constant water bath, consisting of a square box, A, supported over a Fletcher's solid flame burner. The top of the box, 15 x 15.5 in., is formed by a brass plate, ⅛ in. thick, which thus is stiff enough to



Constant Water Bath.

support a considerable weight without yielding, the sides and bottom being sheet copper. From the point, B, projects a ½-in. brass tube, B C, which turns up at right angle. At E is a stop cock, which is connected by a thick rubber tube with the glass tube, D F, which is fastened against the adjoining wall. Connected with C by a rubber joint is a ½-in. block tin tube of 20 ft. length, which extends up the wall in the manner shown to the highest point, T, and thence returns and ends just over the slightly funnel-shaped top of the glass tube at D. The bath being filled with water to just the level, B *b*, may be kept constant by boiling for many days without appreciable loss of water, the steam being condensed in its passage up, or, if uncondensed before it reaches the point, T, in its passage down the block tin tube. In flat-bottomed platinum or porcelain capsules, evaporation goes on very rapidly when placed on top of this water bath. The whole surface of the bath is nickel plated.



Automatic Cut-off for Gas for Drying Chamber.

III
VAPORIZATION

By the term "vaporization" we are to understand certain mechanical operations by which volatile substances are separated from other fixed bodies, or from bodies which may be less volatile, by the action of heat. When a volatile liquid is separated from a less volatile liquid, by the process of vaporization, we have what is known as evaporization. When a volatile liquid is to be collected we have what is known as distillation. When a solid is to be separated from the volatile liquid, we have what is known as desiccation, in which solid substances are deprived of moisture. Excication is the process by which a solid, crystalline substance is deprived of its water of crystallization, by the aid of powerful heat.

Granulation.

This is the process by which a powder is produced by heating a solution until the moisture has evaporated. Many salts are treated in this manner. The heat which should be applied in this process should be strong at first, and then gradually reduced. The stirring should be constant. When vaporization is used to separate a volatile solid from another body, it is known as sublimination. It can also be called a process of distilling volatile solids. It is a process which is largely used in the manufacture of chemicals, and is not so largely used in the laboratory.

Evaporation.

When any liquid is heated for the purpose of expelling vaporizable matter, and the process is conducted solely with a view to saving its fixed portion, the operation is termed evaporation. It thus far differs from distillation, which has for its object the preservation of the volatilized portion, in most cases, regardless of the solid. By its aid we can decrease the volume of or concentrate solutions for crystallization and chemical reaction, expel valueless volatile ingredients from those which are more fixed, obtain dissolved matter in a dry state, and prepare extracts and other pharmaceutical products.

Liquids evaporate more or less at all temperatures, those having the lowest boiling point yielding the most readily; but there are certain conditions which greatly promote this tendency. It must be remembered, therefore:

1.—That evaporation is more rapid in dry atmospheres, and that consequently the transit of a constant stream of air over the surface af the heated liquid effects a continual removal of each stratum as it becomes saturated with vapor.

2.—That evaporation is confined to the

surface, and consequently that the breadth of the evaporating vessel must be extended at the expense of its depth.

3.—That heat greatly facilitates evaporation by lessening the cohesive force of the particles of a liquid, and consequently that the evaporating vessel should present a broad surface to be heated.

4.—That a diminution of the atmospheric pressure also facilitates evaporation, for the more perfect the vacuum the lower the boiling point of a liquid.

For analytical purposes, capsules of Berlin porcelain are by far the best implements. The capsules should be very thin, with steep sides, spout for pouring, nearly flat bottomed, and glazed throughout. Watch glasses answer for small experiments, but require to be very cautiously heated, as they are readily fractured.

Beaker glasses are also used for evaporating solutions which would lose by being transferred. Broad-mouthed glass flasks are of but limited application for evaporating, and are only employed for slow processes with valuable liquids, which are liable to alteration by too much exposure when ebullition is necessary.

For the larger operations of the chemist or pharmaceutist, vessels of copper, tin, enamelled iron, tinned copper, and for some purposes very large porcelain capsules are more suitable.

Retorts are used when the vaporized particles are of sufficient value to be condensed, as in the process of distillation.

Spontaneous Evaporation.

Those liquids which are very volatile or which become altered by heat, are evaporated by mere exposure to the atmosphere at its ordinary temperature. To this end they are poured into broad shallow vessels, and placed aside until the dissipation of all vaporizable matters, or until crystallization; this mode of evaporation being also employed for procuring large crystals, which are better defined than those obtained by rapid evaporation. The more dry and hot the atmosphere the more rapid is the evaporation. In order to maintain a continued contact of the face of the liquid with strata of fresh air, the vessel containing it should be placed in a draught, so that those portions of air which become saturated with vapor may be displaced. When the air might act injuriously, and a vacuum is unnecessary, a substance may be evaporated in another atmosphere, for instance, of hydrogen or carbonic acid. For this purpose it is only necessary to adjust the disengagement leg of the apparatus to the tubulure of a retort, so that its end may reach nearly to the level of the liquid in the latter. The generated hydrogen passes into the retort heated to the required temperature, and promotes the discharge of the vapors into a recipient attached to the beak of the retort, and fitted with a small tube in its other tubulure for the disengagement of uncondensed portions.

For the evaporation of solutions of sulpho-bases, of sulpho-salts, and of all substances readily oxidizable by exposure, this process is better applicable than that with the air pump, which is apt to be attacked when the eliminated vapors are corrosive.

This process is much used in crystallization, for concentrating alterable solutions, and drying precipitates.

Evaporation in Vacuo.

We have already referred to the happy influence of diminished atmospheric pressure in facilitating evaporation, and shall now speak of the means by which it is accomplished, and the particular instances in which it is employed.

This mode is resorted to for hastening the evaporation of all liquids, but more especially of those which are alterable by exposure.

Evaporation by Heat in Open Air.

Having already noted the effects of heat in facilitating evaporation, we proceed to make known its modes of application. As the boiling points of solutions differ, so accordingly their evaporations are effected at varying temperatures. For example, aqueous or other solutions of unalterable matter may be evaporated over the fire; others which are destructible by heat require the intervention of baths. In whatever mode the operation is performed, the general principles are the same, and whether the vessel be a porcelain capsule or metallic pan, the greater its width in proportion to its depth the more rapid is the evaporation. Constant agitation with a stirrer is also promotive of the process.

Evaporation Over Water and Saline Baths.

When solutions are alterable at a temperature of 212° F., the capsule or containing vessel is heated over the water bath. If it requires a higher heat, but one not exceeding 300° F., then the water must be replaced by a saline bath.

Evaporation by Steam.

This mode has many advantages over all others, not among the least of which

is that with the aid of the generator any number of vessels may be heated simultaneously, and in any part of the laboratory, it being only necessary to have conduits of sufficient length to convey the steam to them. Moreover, convenient stop cocks allow a regulation of the heat, and consequently all danger of injury to the evaporating solution is avoided. By increasing the pressure of the steam, the temperature of the solution is also elevated.

Steam is applied through metallic coils placed at the bottom of the containing vessels, and having an exit pipe leading into the neighboring flue, or else by means of metallic casings.

Evaporation Over Sand Baths.

This mode is much used in analyses and for careful evaporations, requiring temperatures greater than 212°, and yet not so high as those given by the naked fire. The position and arrangement of the vessels are as directed under the head *Sand Baths.*

Evaporation by Heated Air.

This mode is admirably adapted for the inspissation of the natural juices of plants or for preparing dry extracts. It is also applicable to the completion of evaporations which have been carried as far as is safe over the naked fire. Porcelain plates or panes of window glass are the vessels used, and a stove or apartment for their reception heated from 95 to 110°, with a free draught passing through are the means of obtaining the required temperature. The juice evaporates either to thin scales or else to a spongy mass, as in the case of tannin extracted by ether, and as soon as it reaches dryness, the plates or panes are to be withdrawn, and their contents removed with a spatula.

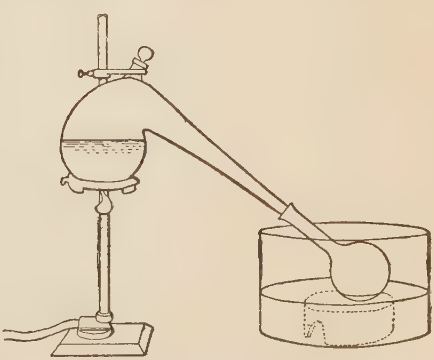
Evaporation Over the Naked Fire.

The tendency of many substances to decomposition over fire, especially organic, even when in solution, renders this mode inapplicable save when the solvent and substance dissolved are both inalterable below the boiling point of the former. It is resorted to for expediting evaporations, but otherwise is far more inconvenient than steam, because of its affording less facility for the regulation of the heat and requiring greater attention. The containing vessel should be placed over a furnace of small dimensions, and its contents continually stirred with a porcelain spatula —this precaution preventing decomposition or carbonization, provided the temperature is not allowed to exceed the boiling point of the solvent.

In analysis and other processes, the heating implement is generally the gas or spirit lamp. The capsule filled to about 2-3 its depth with liquid, being placed in position, the flame is applied gradually and maintained just low enough to prevent ebullition; and in order to facilitate the process, and at the same time to allay turbulence, it should be frequently stirred with a glass rod. The same directions apply when the operation is performed in a beaker glass, as is done in some analytic experiments. A cover of white paper prevents access of dust without retarding the process, but care must be taken that the contents of the vessel be not ejected against it, thus causing a loss. In evaporating to dryness, towards the end of the process the flame must be so managed as to impart a uniform heat to all parts of the thickened solution. The interposition of a very thin plate of sheet iron between the flame of the lamp and the bottom of the heating vessel is an additional means of preventing spirting. These precautions and constant stirring will prevent the loss of particles which is liable to occur upon disengagement of the last portions of liquid. If the liquid drops a powder during the operation, the vessel must be inclined, and in order to prevent spirting, heated above the deposit.

Distilling.

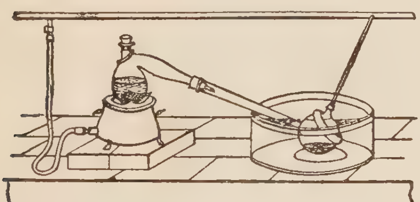
Small Apparatus for General Purposes. —(a) All ordinary distilling apparatus consists of 2 parts—one in which the heat is applied to the body to be distilled and vaporized (called the "still"), and the other into which the vapors that are



A Simple Distilling Apparatus.

formed enter in order to undergo the cooling that condenses them (termed the "condenser"). One of the simplest forms of distilling apparatus used in laboratories consists of a still into which is introduced the liquid to be distilled, and which is placed upon a furnace. The neck of this fits into that of a sphere whose opening must be wide enough to allow the orifice of the still to reach the spherical part of the receiver. Finally, the sphere dips into a vessel full of cold water, and is cooled on its external surface by a wet cloth. The heated mixture begins to boil, and its vapors, escaping from the retort, cool and condense upon the cold sides of the spherical receiver. This latter serves at once as a condenser and a vessel for receiving the distilled product.

In the beginning, the empty receiver weighs less than the volume of water that it displaces, and tends to float. This may be remedied by using a sufficiently heavy ring of lead into which the neck of the receiver may be introduced, and which may rest upon the latter's bulge. Upon fixing a similar ring under the receiver, the latter will be prevented from turning laterally and even from getting broken.



Small Apparatus for General Purposes.

The water in the external vessel is renewed so as to keep it cold.

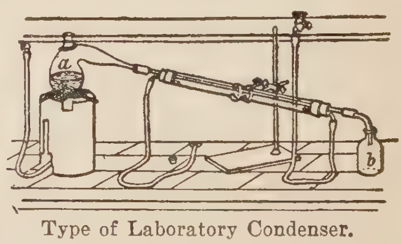
A simple arrangement of this kind is not adapted for materials that have a low boiling point, since a large proportion of the vapor escapes, and makes its exit through the neck of a receiver, which is kept hot by the vapors coming from the still. The following, which is just about as simple, is a much more perfect arrangement.

The narrow part of the still is fixed into the neck of a long, tubular receiver by means of a cork which it traverses. This annular cork exactly closes the space between the neck of the still and that of the receiver. On the other side, in the tubulure of the receiver, there is fixed by means of a cork, perforated and arranged like the preceding, a long and narrow glass tube.

When the still has been filled with the substance to be distilled, and placed upon a furnace covered with wire gauze, the receiver is immersed, as above stated, in cold water. The vapors that are formed become cooled in traversing the elongated neck of the receiver, and are thoroughly condensed in the immersed part, provided the ebullition is not too rapid. In this latter case, the narrow tube, which presents the only open orifice, becomes heated, and indicates to the operator that the fire must be moderated.

The inconvenience of every apparatus of this kind is that the vapors which enter the receiver are not compelled to impinge against the sides, and may go directly to the exit-tube, or, in other words, the refrigeration is not methodical. Moreover, the refrigerating surface continues to diminish in measure as the receiver fills. Finally, if the receiver breaks, the entire distilled product comes in contact with the water. Despite these disadvantages, the rapidity with which such apparatus may be arranged, causes them to be frequently employed.

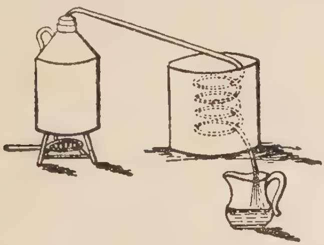
The use of refrigerators permits of a more exact and methodical condensation of the vapors. These are arranged as follows: The 2 orifices are placed in contact by means of a rubber tube, 3 to 4 cm. in length, into one end of which is introduced the neck of the retort, a, and into the other tube of the refrigerator. The latter being held in an inclined position by means of a clamp, a current of water traversing it from top to bottom, and a bent tube being adapted to its lower extremity, the free extremity of the bent one is fixed into the flask that is to collect the product. We may also suppress the central tube of the refrigerator in the flask, b, kept inclined. To facilitate this arrangement, the neck of the retort is cut at a point where it has the same external diameter as the tube of the refrigerator, and is then edged with a flame.



Type of Laboratory Condenser.

Again, if the difference between the diameters is considerable, we may, by means of a flame, draw out slightly the one of the two tubes that is the larger, and cut it at the proper point to obtain an equality in the diameters. Finally, we may solder to the extremity of the refrigerator a cylindrical tube, 2 or 3 cm. in diameter and 6 or 7 in. length, into which is fitted the neck of the retort previously provided with a cork. This latter contains an aperture running in the direction of its axis, and the whole is arranged so as to form a tight joint.

When the substance distilled attacks cork or rubber, the neck of the retort is drawn out to a sufficient length to allow the tube that terminates it to enter the refrigerator to some depth. The rubber with which the two parts of the apparatus are connected is thus nearly out of the range of the vapors.

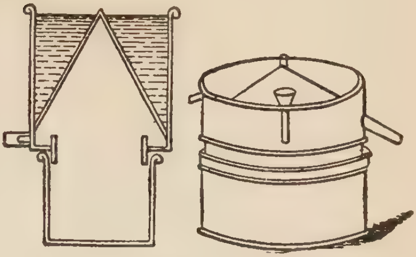


Tin Can Still.

(b) One of the simplest forms of still consists of a tin can or bottle in which the water is boiled, and to this a tin tube is adapted by means of a cork, one end of this tin tube terminating in a coil passing through a tub or other vessel of cold water. A gas burner, as shown, is a convenient source of heat, and in order to insure a complete condensation of the vapor, the water in the cooling tub must be changed now and again.

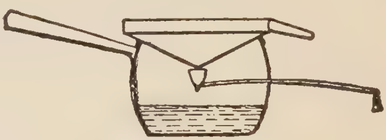
(c) Sometimes the vapor is condensed by being allowed to play against the inside of a conical cover which is adapted to a saucepan, and is kept cool by the external application of cold water; and in this case the still takes the form represented by our next engravings; the condensed water trickles down on the inside of the cone, and flows out at the spout.

(d) An extemporized arrangement of a similar character may be made by passing a tobacco pipe through the side of a tin saucepan as shown in the engraving, and inverting the lid of the saucepan; if the

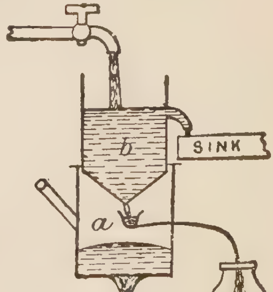


Simple Externally-Condensed Still.

lid is now kept cool by frequent changes of water inside it, and the pipe is properly adjusted, so as to catch the drippings from the convex side of the lid, a considerable quantity of distilled water may be collected in an hour or so.



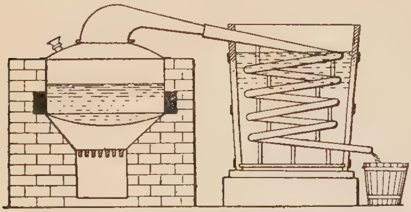
(e) The apparatus shown works admirably, and is very convenient. a is a common tin saucepan, with a small hole in the side, for a tobacco pipe; b, a "steamer," on top, with a bottom like an inverted cone, 1 in. of wire being soldered at the apex.



Tap-Cooled Still.

A gas jet (Bunsen's, if possible) boils the water in the saucepan; the ascending steam is condensed on the lower surface of the steamer, runs down to the point of

the wire, down the pipe into the bottle. A small jet of cold water keeps b cool.

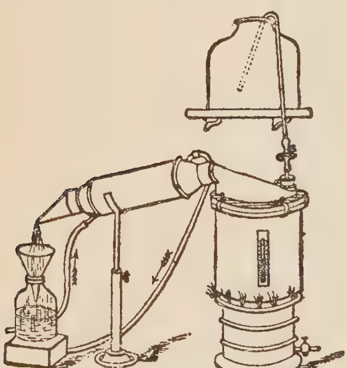


An Old Fashioned But Efficient Still.

(f) The arrangement shown is one that may readily be adapted to, and is specially suited for, the old fashioned stills which are in frequent use among pharmacists for the purpose of distilling water. The idea is extremely simple, but thoroughly efficient in actual practice. The still is thin copper, 2 gal. capacity, and the condenser is the usual worm surrounded with cold water.

Tinctures, Extracts, etc.

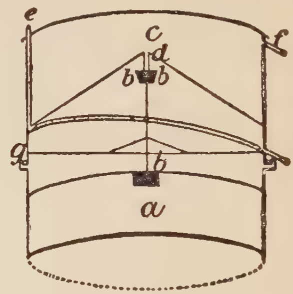
(a) A very convenient and complete still is shown herewith. The body holds



Tincture and Extract Still.

over 3 gal.; the condenser has 7 straight tubes surrounded with the cold water introduced by a rubber from a hydrant or bucket of water placed higher than the still, and carried off as it becomes warmed by another tube as indicated by the arrows. By the siphon arrangement shown in the cut, it is possible to feed the still from a reservoir while distillation is in progress, thus using a 3-gal. still where a much larger one would have been necessary. The still may be set into a kettle partly filled with water, and thus used as a water bath, or a shallow dish, with flat rim, which accompanies the still, may be placed between the two brass ring bands and clamped securely.

(b) Stevens arranged the apparatus as shown for continuous distillation. As soon as the water passes out of the boiler,



Apparatus for Continuous Distillation.

a, the float, b, lowers, letting a fresh supply of water from the condenser, c, through d, thereby keeping the water in the boiler at a constant level. This avoids the necessity of adding a large quantity of cold water at once, the effect of which would be to reduce the temperature of the water below the boiling point.

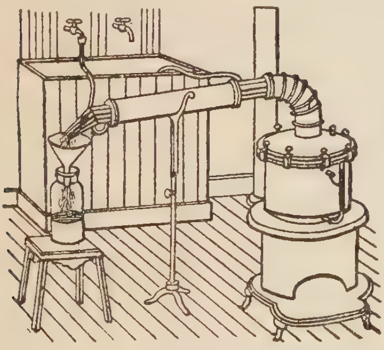
Cold water is supplied to the condenser through e, and as it becomes heated and rises to the top, it is carried off through f. The boiler and condenser are joined at g.

By leaving out the float and closing the inlet, d, with a cork, it can be used for distilling other liquids.

The apparatus is not patented, and should any pharmacist desire to make one for his own use, he can do so.

(c) The distilling apparatus represented herewith is intended primarily for the use of pharmaceutical chemists or druggists, but it possesses features which will recommend it to many who have need of a trustworthy and quick-acting still. The wide delivery tube is a useful feature, allowing as it does for the accumulation of vapor, and permitting the introduction of the hand. The body of the still is of wrought iron or copper, with a lid fitting on ground edges, and held together by screw clamps, as seen in the engraving. A gauge is fitted to show the quantity of

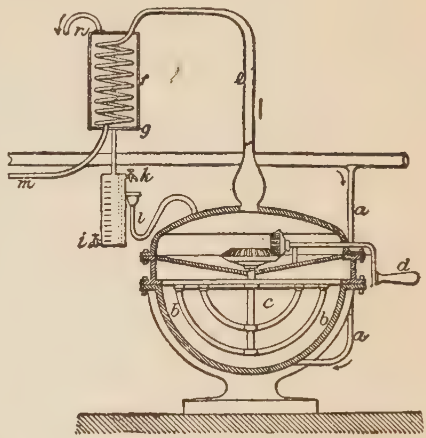
liquid in the still. The cendenser consists of a number of glass tubes, which, if they are 1 in. diameter and 24 in. long, expose a surface of 264 in., while that of the surrounding cylinder is only 188½ in. The ends of the condenser tubes are drawn together and tapered, as shown in cut, to permit, if desired, the collection of the distillate in a narrow-mouthed bottle. The advantage gained by this apparatus, aside from the general one of convenience, is thus seen to be in the notable increase of condensing surface it exposes, which to that extent increases the effectiveness of the device, *i.e.* its rapidity of action. Compared with a Liebig condenser of similar dimensions, this apparatus exposes probably 3 times as much condensing surface. The idea of a tubular condenser, employed in the manner set forth, is, in the opinion of the *American Journal of Pharmacy*, an excellent one, that may find useful imitation in the chemical laboratory and elsewhere. The device illus-



Remington's Still.

trated and described was invented by Joseph P. Remington, whose recommendation of its merits is based upon a continuous use of it for years.

(d) *Flowers, Plants or Seeds.*—To obtain the essential oils, from flowers, plants or seeds, the oleiferous material is placed in an iron, copper or glass still, of 1 to 1,000 gal. capacity, and is covered with water; superposed is a dome-shaped lid, terminating in a coil of pipe, placed in a vessel of cold water, and protruding therefrom with a tap at the end. On boiling the contents of the still, the essential oil passes over the steam, and is condensed with it in the receiver; the oil and water separate on standing. A great improvement, introduced by Drew, Heywood and Barron, is the use of a steam-jacketed still, as shown. Steam is supplied from a boiler by the pipe, a, into the jacket, b; within the head of the still is fixed a "rouser," c, a double-branched stirrer curved to the form of the pan, and having a chain attached and made to drag over the bottom, the whole being set in motion by means of the handle, d. The still is charged, and nearly filled with



Steam Jacketed Still.

water; the head is then bolted on, steam is admitted into the jackets, the contents are well stirred, and soon the oil and steam are carried up the pipe, e, condensed in the refrigerator, f, and let out at g into the receiver, h. Here the oil and water separate, and escape by different taps. In the illustration it is supposed that the oil obtained is heavier than water; it will then sink, and be drawn out by the lower tap, i, and as son as the water reaches the level of the upper tap, k, it will flow into the siphon-funnel, l, and thence into the still. Thus the same water is repeatedly used in the still. The pipe, m, conveys cold water into the refrigerator f; the water escapes as it becomes hot by the pipe n. When the oil distilled is lighter than water, the taps, i k, exchange duties Before commencing operations the siphon, l, is filled with water to prevent the escape of vapor.

Spirit.

(a) The distillation of spirit is performed for the purpose of separating the alcohol more or less from the water. The boiling point of water at the ordinary

standard pressures of the atmosphere, equal to 30 in. of mercury, is 212° F. (100° C.), that of alcohol 173.1° F. (78.5° C.). At the sea-level, the pressure of the atmosphere may frequently vary between 28.5 and 30.5 in.; the boiling points of water corresponding to these temperatures are 210° F. and 213° F. Indeed, changes in the weather may cause the boiling point of water to vary as much as 5° F. in our climate. These alterations in pressure would cause corresponding changes in the boiling point of alcohol. If we gradually raise the temperature of alcoholic fluids to a point when vapors are freely formed, it is observed that though there is a continuous absorption of heat, yet the liquid does not increase in temperature. The heat which is absorbed during the first period is doing work of a different character from that employed subsequently. There are two phases in the process, and two different kinds of work performed by the heat employed in boiling even a kettle of water.

The first phase is indicated by a rise of temperature from 60 to 212° F.; the second phase by a change of state, from that of a liquid at 212° F. to a vapor at the same temperature. The quantities of heat required by different liquids in these changes varies greatly, but the variation is greatest when they pass through the second phase. Thus 1 lb. of steam at 212° F., if converted into water at 212° F., will give up heat sufficient to raise 996 lb. of water from 60 to 61° F. The heat rendered up by 1 lb. of alcohol vapor at 173° F. during condensation to liquid at 173° F., will heat 374.9 lb. of water from 60 to 61° F. These figures are sufficient to show that a small quantity of steam will boil a large quantity of alcohol. Stills of improved construction depend upon this principle.

When a mixture of alcohol and water is distilled, the liquid will not boil constantly at 173° F. until all the alcohol has passed over, but will rise in temperature gradually throughout the distillation until 212° F. have been reached. The distillate, if separated into fractions boiling between fixed points, consists of a series of mixtures of alcohol and water in definite proportions. The mixtures richest in alcohol come over first; that is to say, at the lowest temperature.

The latent heat of the vapor of a liquid with a high boiling point can be made to boil a liquid with a lower boiling point. For instance, steam at 212° F. can boil alcohol at 173° F., and alcohol at 173° F. in turn can boil ether at 94.8° F. With a simple still, strong alcohol can be obtained from wash by repeated distillation only. Woulffe realized the fact that this wasteful and tedious process could be dispensed with by connecting together a number of rectifying chambers in such a manner that the vapor driven off from the chamber nearest the fire should be condensed in the second, and by the heat given out by its condensation cause the more volatile portions of the liquid of the second to distil into the third chamber, and those of the third into the fourth, and so on, until a sufficient degree of concentration is attained.

IV

PRECIPITATION AND SEPARATION

Edulcoration.

The affusion of water on any substance for the purpose of removing the portion soluble in that liquid. Edulcoration is usually performed by agitating or triturating the article with water, and removing the latter, after subsidence, by decantation or filtration. It is the method commonly adopted to purify precipitates and other powders which are insoluble in water. The washing bottle is a most useful instrument for the edulcoration of precipitates.

Precipitation.

By precipitation we are to understand a process of separating a solid substance from a solution by the action of chemicals, heat, or light. The precipitate easily drops to the bottom of the receptacle, although sometimes it may rise or be held in suspension. The solid substance is called the precipitate; the added agent which produces the effect is called the precipitant, while the liquid which remains in the vessel is called the supernatant liquid. Precipitation is one of the most valuable aids to the analytical chemist, and is constantly employed, but is also of great use in the arts. It is sometimes used to bring the substance into a powdered state; again, it is used for purification, or to separate substances which are insoluble in the liquid. It is sometimes necessary to heat the solution in order to obtain precipitation. Some preparations, such as silver salts, are precipitated by the action of light. A special precipitating jar is inexpensive, and is very convenient. The precipitated matter is usually collected with the aid of a filter and a filter paper.

Straining.

Straining is best accomplished through some textile fabric, as felt, muslin, Canton flannel, gauze, etc. Felt strainers are particularly recommended where chemical work is being done, but for the amateur's use they are apt to be expensive, as the felt takes up a great deal of the odor of the material. Canton flannel is cheap, and the bleached Canton flannel is recommended. One or two funnels or tunnels should be provided. The white enameled ones, which are imported from Sweden, are particularly recommended. Hard-rubber funnels are good for certain purposes; also copper funnels. Special funnels are provided for hot filtration, as shown in one of our engravings. This is particularly recommended when we deal with preparations containing wax, jellies, ointments, etc. The jacketed hot-water funnel is perhaps the most convenient means of obtaining heat. Steam may also be used. if available, and is both cheap and handy.

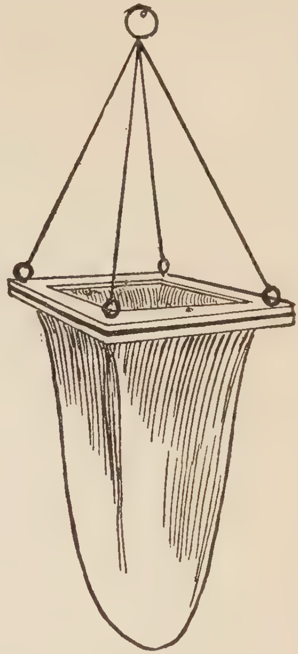
Colation.

Colation or straining is a process which does not differ from filtration in principle, but the term is applied to the removal of insoluble particles of a relatively large size by passing the liquid through a medium of coarser texture than filter paper. The ordinary straining media are felt, flannel, muslin and calico, through which materials the liquid will flow with considerable rapidity.

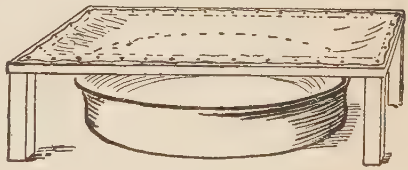
A seamless felt straining bag is illustrated. A strainer of this kind is particularly useful for straining large quantities of syrups or liquid extracts. When in use it is suspended by means of tapes over a suitable receiver, or is supported by a frame, as is shown in the figure.

Our next engraving illustrates a form of strainer which is used when bulky precipitates are required to be filtered, washed and drained. Ferric hydroxide is precipitated in large quantities for the manufacture of the scale preparations of iron, and it is conveniently separated and washed on a piece of strong calico stretched over, and fastened by means of nails, to a rectangular wooden frame supported on short wooden legs. In this case it should be noted that the precipitate is wanted; the filtrate is allowed to run to waste.

Small quantities of liquid—an infusion or decoction, for example—may be strained through a piece of muslin or calico stretched over the top of an ordinary funnel.



Straining



Large Strainer

Clarification.

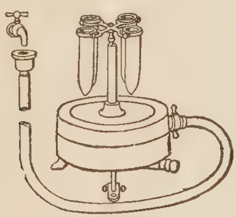
Clarification is the process of separating the suspended matter contained in a liquid or semi-liquid substance without recourse to filtration. It may be effected in a variety of ways. The official method adopted for the clarification of honey, the viscid nature of which renders ordinary filtration somewhat impracticable, is the application of heat. The honey is heated on a water bath in an open, shallow dish, under which treatment it becomes much

more fluid, and the suspended particles of solid matter rise to the surface, or sink, according to their specific gravity. By skimming, or by straining through flannel while the honey is still hot, the solid foreign particles can be easily separated out. In the same way, vegetable juices can be clarified by heat, albuminous material forming a coagulum which can be separated by filtration.

Certain liquids which are difficult to filter, and which do not yield a satisfactory filtrate, are sometimes clarified by the use of white of egg or of gelatine. In the former case a relatively small quantity of the white of egg is thoroughly mixed with the turbid liquid, and the whole is then heated to about 80° C., at which temperature white of egg coagulates. The particles which rendered the liquid turbid are enclosed in the coagulum formed, which is easily removed from the liquid by the ordinary process of straining. Gelatine is useful, particularly when the turbidity of a liquid is due to tannin bodies, with which the gelatine readily combines to form an insoluble gelatine tannate, which can be readily removed by filtration through paper or by straining through calico.

Centrifugation.

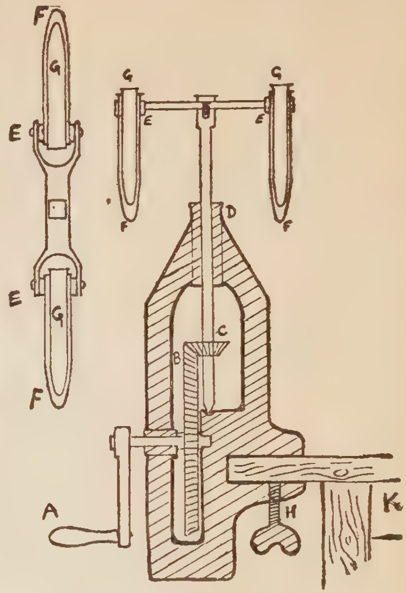
By centrifugal force is meant the force exerted by any whirling body. A solid



Water-Drive Centrifuge

body contained in suspension in a liquid can be readily separated by rapid rotation, the heavier particles of solid always tending to fly to the outer rim of the revolving ring of fluid. Centrifugation is thus another means of separating a solid from a liquid, and is a method especially useful when dealing with small quantities of liquid which contain in suspension minute quantities of a solid body which it is difficult to collect satisfactorily on a filter paper.

Centrifugal machines -re constructed to various patterns, but the simple form

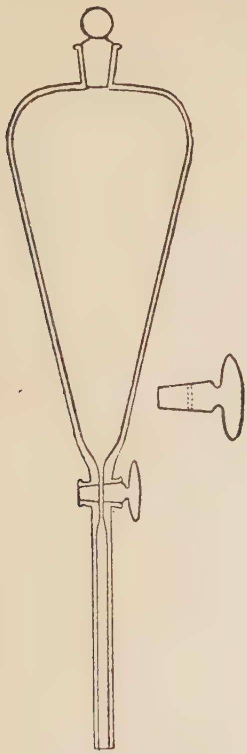


Centrifuge

illustrated will serve to show the principle of their construction. They consist essentially of two or four, or sometimes more, glass tubes (G) enclosed in metal tube holders (F), the tubes themselves being constructed with a somewhat conical-shaped bottom. The tubeholders are swung upon a horizontal axis (E), which can be rotated at a rate of from 2,000 to 3,000 revolutions a minute. The whole apparatus is clamped firmly to the laboratory bench, as shown in the figure. When in use, the tubes are filled with the liquid so that they are equally balanced, and the machine is turned rapidly for a few minutes, at the end of which time the solid particles will be found compacted together at the bottom of the glass tube, leaving a clear layer of supernatant liquid, which can be poured off.

A centrifuge is used in the laboratory for the rapid determination of fat in milk. A measured quantity of the milk is put into a graduated centrifuge tube and a little amylic alcohol, hydrochloric acid, and some concentrated sulphuric acid are added, in order to secure a better separation of the fat. A second tube, containing a similar quantity of liquid, is placed

on the opposite side of the machine in order to secure a proper balance, and the apparatus is then rotated for one or two minutes, at the end of which time all the fat will have collected in the neck of the



Separating Funnel

tube, and the percentage can be directly calculated. The centrifuge is also extremely useful for collecting for microscopical examination the deposit in a small quantity of liquid, the deposit in a sample of urine being best collected in this way.

The Separation of Immiscible Liquids.

The separation of two liquids which are more or less insoluble in one another is an operation important in many pharmaceutical and manufacturing processes. When relatively large quantities of immiscible liquids have to be separated, a tubulured jar or a siphon may be used, as has been already described under DECANTATION; but for quantities of a few ounces some other means must be adopted.

The alkaloidal assay of the galenical preparations frequently necessitates the separation of a layer of ether or chloroform or other organic liquid from a watery solution with which it is immiscible. In the assay of opium, for example, a layer of mixed alcohol and ether has to be separated from an aqueous layer, and in this case the Pharmacopœia directs the use of a pipette. A pipette, as shown, consists of an elongated bulbed glass tube, open at both ends, the lower end being drawn out into a narrow orifice. It is used by dipping the lower end under the surface of the top layer of liquid and applying suction with the mouth at the upper end of the tube. The bulb may be large enough to hold from 5 to 50 mils, and when as much as possible of the layer has been drawn into the bulb the moistened tip of the forefinger is placed firmly over the upper end of the tube, the liquid being thus kept from flowing out until the finger is removed. A glass syringe may be used for the same purpose as a pipette, but it is somewhat more clumsy.

Separating Funnels.

A more convenient means of separating layers of immiscible liquids is by the use of a glass separating funnel. An elongated pear-shaped separator, as illustrated, is a good form by means of which two liquids can be separated with greater accuracy than with a separator of a cylindrical shape.

For the separation of two liquids neither of which is particularly volatile, an ordinary glass funnel, the neck of which is provided with a stopcock, is sometimes used, but a separator of this pattern is quite unsuitable for assay processes, since it is impossible to shake the two layers together before they are set aside to separate.

Decolorization.

Decoloration is a process of rendering colored liquids colorless, and this is accomplished by the aid of animal charcoal or bone black. Decolorization may be accomplished in an ordinary filtering funnel or in a percolator.

Filtration and Other Processes of Separation.

Filtration is a process of separating a liquid from solid matter mechanically sus-

pended in it, by passing it through some porous medium which does not allow the solid particles to pass through. In some cases it has for its object the collection of the suspended matter; in others it is used for obtaining the liquid in a clear state. Filtration is a simple process in principle, but in manufacturing, as well as in processes on a smaller scale, where liquids are employed, there is perhaps no operation of wider application, hence it is of great importance that the process shall be carried out in an economical and expeditious manner. Among the substances which are used as filtering media are various kinds of cloth, flannel, unglazed porous paper, engineer's waste, absorbent cotton wool, glass wool, asbestos, sand and charcoal. For small quantities of a liquid which filters easily, and in which the suspended matter is in coarse particles, a pledget of absorbent cotton wool placed in the throat of a funnel is often sufficient to produce a satisfactory filtrate. For extensive laboratory processes, however, the latter simple device is seldom of much service, for the small extent of filtering surface will soon lead to imperfect filtration, or possibly to complete blocking of the filter. The form of filter used, and the character of the filtering medium, depends not only upon the nature of the liquid to be treated, but also upon the amount of liquid that is required to be filtered.

Filtering Media.—Of the filtering media in common use, fine porous unglazed paper is the most universal for small operations, a piece of paper of suitable size being folded into a cone and fitted into a funnel. The funnels used for supporting filter papers are made of glass, glazed earthenware, or of metal, and those which are intended for rapid filtration are usually deeply ribbed or fluted on the inside, the space between the filter paper and the glass permitting a free passage of the filtered liquid. The same end is sometimes attained by placing thin glass rods or quills between the filter paper and the sides of the funnel. Filtering paper may be obtained in many qualities, the best quality consisting of practically pure cellulose. For the majority of purposes, white filter paper should be used, and this is made from pure flax fiber. The gray paper, on the other hand, contains a varying amount of wool, and although on account of its low cost it is used for the filtration of some galenical preparations, it is liable to color certain solutions, particularly alkaline ones, yellow. Such paper frequently contains also a considerable amount of chlorides, calcium carbonate, and iron salts, all of which are liable to pass into solution. For analytical work, particularly in ignition processes, a Swedish filter paper of very fine quality is necessary; such filter papers, in the course of preparation, are washed with hydrofluoric and hydrochloric acids, and by this means are rendered practically free from mineral impurities, and yield, on ignition, a very minute quantity of ash.

The suitability of filter paper for ordinary pharmaceutical purposes may be determined by the application of a few simple tests. Distilled water which has been passed through the paper should leave no residue on evaporation, showing that the paper contains no soluble mineral substances. Similarly diluted hydrochloric acid, after passing through the filter paper, should give none of the reactions of the alkaline earths, while the paper should not blacken with ammonium sulphide, proving the absence of many of the metals; nor should it be colored by a solution of salicylic acid, which would indicate the presence of iron.

Methods of Folding Filtering Papers.—Filtering paper is sold cut into circles of varying diameter, and since these circles merely require doubling for use, they are much more convenient than the square sheets of paper, which must be trimmed after folding. Plain filters are made by doubling the circle of paper in half to form a semicircle, and then folding it again in half, so as to form a triangle, with a convex base. This, when opened out (Fig. 1), should fit exactly to the sides of a properly constructed funnel, the sides of which should be inclined at an angle of 60°. A filter paper folded in this way is good enough for many purposes, but it has the disadvantage of presenting three thicknesses of paper to one-half of the funnel and only one thickness to the other half; while, assuming that the funnel used has plain and not fluted sides, the filtration will not proceed with

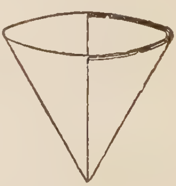


Fig. 1

The "plaited filter" affords a means of furthering rapid filtration, and at the same time it overcomes the objection of the unequal distribution of the paper on as much rapidity, since the sides of the paper will fit closely to the glass.

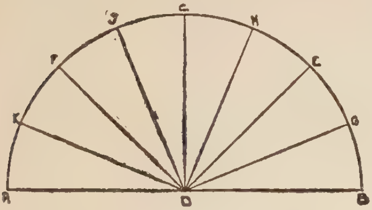


Fig. 2

the sides of the funnel. The method of folding a plaited filter can be best explained by the help of diagrams. The circle of paper must first be folded twice as directed for the plain filter, but having made the crease DC (Fig. 2), the paper is opened out again into a semi-circular form. It is next folded so that DB lies over the crease DC, and DA is likewise made to lie over DC. This operation will produce the creases DE and DF (as in Fig. 2). Next, DB must be folded over to DE and also over to DF, and in the same way DA must be folded over to DF and DE. In this way, when the paper is flattened out, it will be marked by seven creases, radiating from the center, D (as shown in Fig. 2), and the semicircle will be divided by these creases into eight segments. Up to the present all these creases have been made in the same direction, and now, to complete the filter, each segment must be divided by another crease *made in a direction opposite to those already made.* To effect this, DB is folded back so that it lies under DG, on the opposite face of the semicircle; in other words, the new crease DL (Fig. 3) is in an opposite direction to any of the other creases previously made. In a similar fashion, DG is folded back so that it lies under DE, producing a new crease, DM (Fig. 3), which has the same direction as the crease DL, but is in an opposite direction to DG or DE. This process is repeated until the semicircle is divided into sixteen segments by fifteen creases, the eight new creases (illustrated by dotted lines) all being in an opposite direction to the first seven creases. The paper can now be opened out, as shown in Fig. 4, and it will be found divided into thirty-two segments, two of which, situated opposite to one another, have both edges in the same direction, and in order to prevent these two segments from lying flat against the glass when the paper is placed in a funnel a new crease, pointing inward, should be made in each segment so that each of these two segments is divided into two smaller segments, bringing the total up to thirty-four. When placed in a funnel the paper will not fit closely to the glass, and thus a free passage of the filtered liquid is possible, while at the same time the entire surface of the paper will be exposed to the liquid.

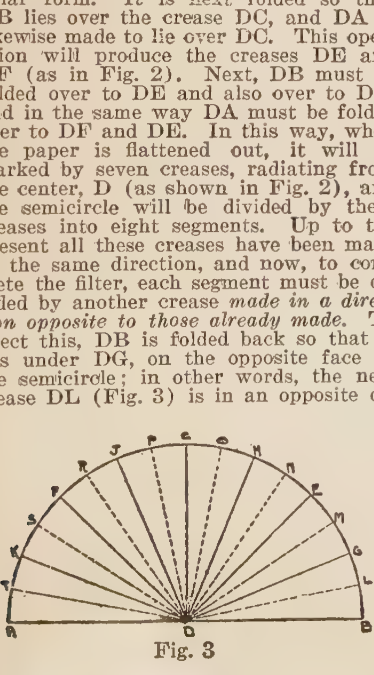


Fig. 3

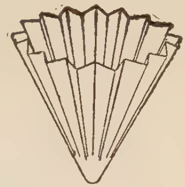


Fig. 4

When plaiting a filter, care should be taken not to crease the paper down to the extreme center of the circle (D), otherwise the apex of the filter may be so weakened as to break with the weight of the liquid poured upon it. The weakest part of a filter paper, whether plain or plaited, is always the extreme apex, and various suggestions have been made with a view to overcoming this weakness. One method is to dip the apex into strong nitric or sulphuric acid; the latter acid converts the paper into parchment paper, and thus renders it impervious to the passage of fluids, but the former treatment merely toughens the fiber of the paper. In either case care must be taken to wash the filter free from all traces of acid. The apex of a filter may also be supported by a small cone made of platinum foil, or more simply by means of a smaller filter paper folded and placed in the funnel first,

or a pledget of cotton wool may be used for the same purpose. When filtering large quantities of liquid the paper is sometimes supported with calico to avoid breakage, the cloth is usually folded up with the paper, the double filter being

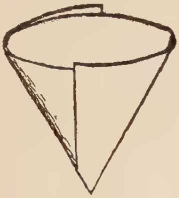


Fig. 5

placed in the funnel in the usual way. The fact that the apex of a filter paper is always a source of weakness has led to the adoption of another method of folding filter papers. The circle of paper is, as usual, first folded into a semicircle. Next, EB (Fig. 6) is folded over, with the crease in the position marked by the line EH; the point E, it will be noted, is not the center of the circle of filter paper. The paper is now turned completely over, and DA is folded over in the position marked by the line, DF, the crease,

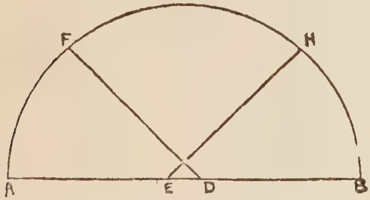


Fig. 6

DF, being, of course, in the opposite direction to the first crease, EH. When the paper is opened out (Fig. 5), it will fit into a funnel having the proper angle of 60°, while the apex will be strengthened by the presence of a double thickness of paper.

A liquid should never be poured in a sudden stream on to the apex of a filter paper, but should always be poured gently against the side of the filter, where, if dealing with small quantities, it may be conveniently directed by means of a glass rod (as shown in Fig. 7). In this figure the student should note the small strip of paper (A) inserted between the neck

Fig. 7

of the flask and the funnel tube. This precaution is necessary if the end of the funnel fits closely into the receiver, in order that there may be a free escape of air as the filtered liquid enters the receiver. A filter paper placed in a funnel should never reach above the rim of the funnel, for, if such be the case, the liquid will be sucked by capillary attraction into the projecting edges, and there will be considerable loss by evaporation from the exposed edges. Even when the filter paper does not protrude over the rim of the funnel there is always some loss by evaporation, especially when the liquid is a particularly volatile one, and the room temperature is high. In order to lessen the loss by evaporation during a slow filtration, a piece of plate glass may be placed on the top of the funnel.

Continuous Filtration.—It is frequently inconvenient for an operator to give constant attention to a filtration process, hence a "self-feeding" filter is of great service. On a small scale, the following simple method, illustrated in Fig. 8, works well. An inverted Winchester quart, containing the unfiltered liquid, is arranged

at such a height that the mouth of the bottle is in the liquid at the level at which it is desired to keep the funnel filled. The liquid in the funnel acts as a valve, and until air enters the bottle none of the liquid will flow out, since the atmospheric pressure is sufficient to support a column of water 32 ft. in height. As, however, the liquid in the funnel passes through the filter, it sinks in due course below the

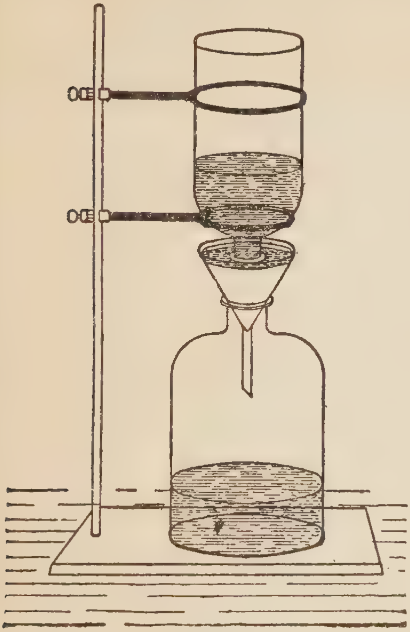


Fig. 8

level of the mouth of the bottle. Air will, consequently, enter, and at the same time a corresponding amount of the liquid will flow from the bottle into the funnel. This process will go on automatically until the bottle is empty. The method is similar to that adopted for obtaining a continuous supply of menstrum for percolation, a process which has been already described. An arrangement which is similar in principle to the above has been adopted for the continuous washing of a precipitate. In Fig. 9 is shown a specially constructed tube fitted into the neck of an inverted flask by means of an india-rubber cork. As in the case of the inverted Winchester, water will flow out of the flask at E as soon as the level of the liquid in the funnel falls below the level of where the side tube joins the main tube (C), air entering the flask through the open side tube (D). The process is continuous so long as any liquid remains in the inverted flask.

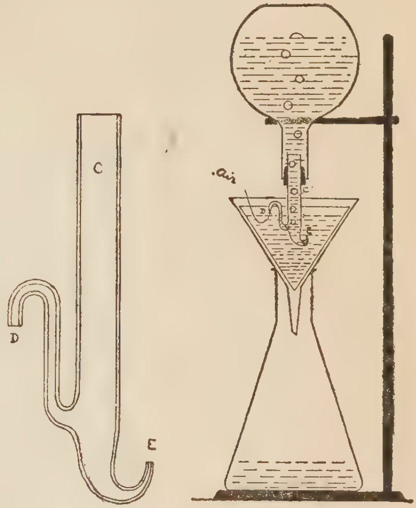


Fig. 9

Asbestos Filters.—In some cases, the turbidity of a liquid is due to the suspension in it of particles of matter so minute that their removal is not easily effected by the ordinary method of filtration through paper. In such cases, a clear and bright filtrate can often be obtained by shaking up with the turbid liquid some substance by means of which the minute particles are entangled, and can no longer pass through the pores of the filtering medium. For this purpose, paper pulp, prepared from waste scraps of filter paper, calcium phosphate, kieselguhr, kaolin, French chalk, magnesia, and finely shredded asbestos, have all been recommended. Whichever one of these substances is chosen, a small quantity of it is well shaken up with the liquid to be filtered, or the filter itself is first coated by shaking up a little of the filtering agent with water, pouring the mixture over the filter and allowing the latter to drain. Usually, with either method, the first few drops of the filtrate are not very clear, hence

the first runnings should be returned to the filter until the filtrate is obtained bright.

For rapidly filtering turbid liquids, especially those which are cloudy from the presence of minute globules of essential oil, the "Seitz" asbestos filter has proved successful. The apparatus consists of a conical filter of fine brass-wire gauze, suitably supported. The turbid liquid is thoroughly shaken with a small quantity of finely shredded asbestos fiber, and is then transferred directly to the gauze filter. With most liquids, a rapid flow of bright, transparent filtrate is obtained.

Hot Filtration.—It is sometimes necessary to filter through paper substances, such as fats and waxes, which are not liquid at ordinary laboratory temperature. In such a case, a rough and ready plan is to arrange the funnel over a circular low-power gas burner (Fig. 10), but a better plan is to use a hot-water jacket for the funnel. In Fig. 11 a funnel suitable for hot filtration on a small scale is illustrated. The jacket is usually constructed of copper; at some point around the top rim there is an opening (A) through which water is introduced, and this water is kept at the desired temperature by means of a Bunsen gas burner or a spirit lamp placed under the projecting arm. In practice, the substance to be filtered is first melted, and is then poured into the funnel, which has previously been allowed to become properly heated in the copper jacket. As the heating is continued, some of the water in the jacket will be lost by evaporation, since the opening, A, must not be closed

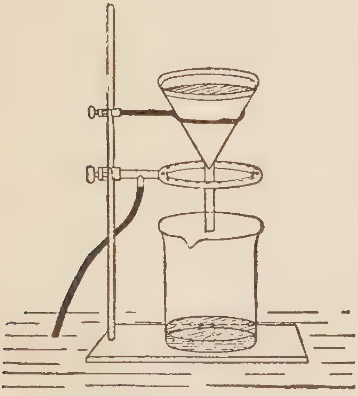


Fig. 10

on account of the pressure which the steam would produce if this were done; hence from time to time a little more water must be poured into the jacket. Fig. 12 shows an improved type.

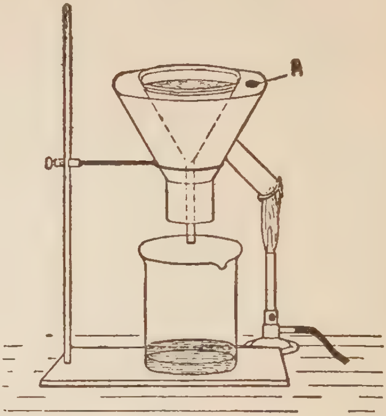


Fig. 11

Accelerated Filtration.—The rapidity at which filtration is effected depends upon several factors, the chief of which are: The extent of the filtering surface, the viscosity of the liquid, the porosity of the filtering medium, and the pressure or force by which the liquid is impelled through the pores of the filter.

In filtration as ordinarily carried out, the only pressure exerted is that due to the liquid itself resting on the filtering medium; but by increasing the height of this column of liquid the pressure is increased, and filtration is consequently accelerated. One of the principles of hydrostatics is that the thrust exerted by a liquid of given depth on the base of the containing vessel is independent of the shape of the remaining portion of the vessel, hence the column of liquid need not be of equal diameter throughout in order to produce uniform pressure.

Acting on this principle, a simple means of filtering oils or other liquids has been suggested. A filter bag is firmly attached to the lower end of a long tube, while to the upper end of the tube is fixed a funnel, into which is poured the liquid that is required to be filtered. Under such conditions the pressure exerted is that due to the weight corresponding to the total height of the column of liquid,

and the filtrate is forced through the filter bag and collected. Instead of a filter bag an ordinary inverted funnel may be used; the filtering medium is tied securely over the broad mouth of the funnel, it being necessary always to support filter paper between layers of calico.

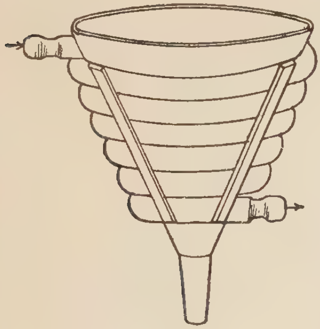
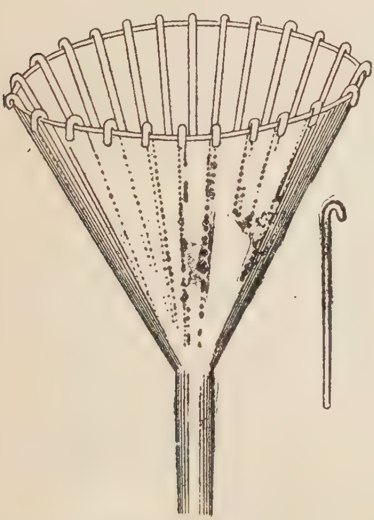


Fig. 12

A Device for Rapid Filtration.

Glass filter rods with a hooked end set over the edge of the ordinary funnel, form a corrugated support for filter paper, which is unaffected by liquids likely to be filtered through the glass funnel, and can be effectually cleaned with a minimum of labor.



Glass Filter Rack

Percolation.

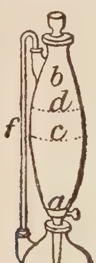
This is a kind of filtration, commonly called "by displacement," employed for extracting the essence from roots, herbs, seeds, barks, etc. It is effected in the following manner: It is first necessary that the articles to be acted upon should be ground in a drug mill to the condition of a coarse powder; then moisten the mass thoroughly with alcohol, allowing it to "macerate" for 12 hours in a vessel well covered. Next is required a hollow instrument of cylindrical form, having one end shaped like a funnel, so that it can be inserted in the neck of a glass bottle, and having inside, near the lower end, a partition pierced with numerous small holes, like the strainer of a French coffee pot, which is a simple coffee percolator; in the absence of such a partition, soft cotton, or any insoluble substance, may be substituted, and being placed in the inside at the lower end of the instrument, will answer as well as the strainer. This instrument is called a percolator. Boullay's filter or percolator is usually employed. Macerate the ingredients to be acted upon, for the time named, introduce them into the percolator, and slightly press them upon the partition. Any portion of the liquid used in the maceration not absorbed by the powder should be poured upon the mass in the instrument, and allowed to percolate. Now gradually pour into the percolator sufficient of the alcohol, or other liquid to be filtered, to drive before it, or "displace," the liquid contained in the mass; the portion introduced must, in like manner, be "displaced" by another portion, and so on till the required quantity of filtered liquor is obtained. This extract is called a tincture. In case the liquor which first passes through should be thick and turbid, again introduce it into the instrument, being very careful not to have the powder too coarse or loosely pressed, or it will permit the liquid to pass too quickly; and, on the other hand, it should not be too fine or compact, or it may offer an unnecessary resistance. Should the liquor flow too rapidly, return it to the instrument, and close it beneath for a time, and thus permit the finer parts of the powder to subside, and cause a slower percolation.

The first portion of liquid obtained by the method of displacement is always in a state of high concentration. In gen-

eral, it is a simple solution of the soluble ingredients of the crude drug in the fluid employed. But sometimes the solvent, if compound, is resolved into its compound parts, and the fluid which passes through it at any given time is only one of these, holding in solution only the most soluble parts of the drug.

Thus, if diluted alcohol be poured over the powder of myrrh, in the cylinder of the percolator, the fluid which first drops into the receiver is a solution of an oily consistency, chiefly composed of rosin and volatile oil dissolved in alcohol. In like manner, when the powder of gallnuts is treated in the same way by hydrated sulphuric ether, two layers of fluid are obtained, one of which is a highly concentrated solution of tannin in the water of the ether, and the other a weak solution of the same principle in pure ether. In all cases, therefore, in which it is not otherwise directed, it is absolutely necessary to agitate the several portions of the liquid obtained by percolation together, in order to insure a product of uniform strength or activity.

To illustrate the operation of displacement, and describe an excellent percolator for making perfume tinctures, we will suppose that benzoin is under treatment. The apparatus, made wholly of glass, having been arranged, as shown, and a plug



Percolator for Perfume

of raw cotton dropped loosely at a, the benzoin, in coarse powder, is then poured into the portion, b, until it reaches the line, c. Alcohol, 95%, is next added until it rises to the line, d. As soon as the first portion sinks into the benzoin a fresh addition must be made; and thus the succeeding relays go on displacing those which preceded them without mingling with them. Each stratum becomes more and more charged with soluble matter as it descends; and when it reaches the bottom of the mass, under the pressure of the superincumbent liquor, it runs out saturated. When, by successive additions of fresh alcohol, the benzoin under treatment has become exhausted, the liquid passes through the mass and falls into the receiver, e, as tasteless and colorless as when first poured in. This indicates the completion of the process.

As atmospheric pressure is an important element in the operation, it will not answer to shut it off by closing the top of the displacer without making some compensation; and, therefore, a communication between the upper and lower vessels is established by means of a latent tube arrangement, f. In this manner the apparatus is kept close, and the evaporation of alcohol prevented, while the pressure produced is distributed throughout the apparatus, and rendered uniform. As the runnings are clear, filtration is rarely necessary. The quantity of alcohol thus consumed need not be more than sufficient to exhaust the material; and the resulting tincture must therefore be diluted to the proper strength. For perfumes, deodorized alcohol must always be used.

The method of displacement has the advantage of expedition, economy, and yielding products possessing uniformity of strength, but it requires considerable experience to adapt it to all substances. The art rests in properly packing the ingredients in the cylinder, some substances requiring considerable pressure to be used, while others, when even lightly packed, scarcely permit the fluid to pass through them. An excellent plan, applicable to all substances, but especially those of a glutinous or mucilaginous nature, is to mix the powder with an equal bulk of well washed sand before rubbing it up with the menstruum. The coarseness of the powder must also be attended to. Substances that readily become soft and pappy when wetted by the menstruum should not be used so fine as those that are more woody and fibrous. The method of displacement answers well for the preparation of all tinctures that are not of a resinous nature, and for most infusions of woody and fibrous substances, as roots, woods, barks, leaves, seeds, insects, etc. It is especially adapted for the preparation of concentrated infusions and essences, as they may thus be obtained of any required strength, without loss, or requiring concentration by heat, which is so destructive to their virtues.

When ordinary tinctures are made in

large quantities, displacement is never likely to supersede maceration on account of any practical advantages it may possess. If the prescribed directions be duly attended to, the process of maceration is unexceptionable. The process is more simple than the other; the mode of operation more uniform; it is, in fact, always the same; it requires less of skill and dexterity in conducting it; it requires less constant attention during its progress, which, in operating on large quantities, is a consideration; and finally, the apparatus required is less complicated. When, however, only small quantities are to be made at a time, and kept in stock, the adoption of the process of displacement will often be found convenient and advantageous. It offers the means of making a tincture in two or three hours, which, by the other process, would require as many weeks.

Dialysis.

This is a process of separating substances which do not crystallize from those which do, by means of a porous diaphragm which sets in water. The apparatus which is used is called a dialyzer, which consists of a cylinder over whose bottom is secured a sheet of parchment paper. This sets in a dish of water. The liquid which is to be treated is placed in the upper dish, and the whole is put away for a time, when the separation will be found complete. This process is more useful in pharmacy than in the arts.

Crystallization.

When a body, in the act of passing from a liquid or gaseous to a solid state, arranges itself in symmetrical forms, the process is termed crystallization, and the parts of the body so aggregated are called crystals.

By this process we can separate crystallizable from amorphous substances dissolved in the same menstrua; purify crystals from foreign and coloring matters, and in qualitative examinations be enabled to determine the composition of bodies by a reference to the characteristics of figure.

The modes of crystallization are by *fusion, sublimation, solution* and *chemical reaction.*

Crystallization by Fusion.—Sulphur, lead, bismuth, tin, antimony, silver, numerous alloys, anhydrous salts, and other fusible substances which are unalterable by heat, are crystallizable by *fusion.* To this end they are melted at the lowest possible temperature, and allowed to cool very gradually. As soon as a crust forms upon the top, which may be readily seen by the surface becoming furrowed, it must be pierced with a rod, and the still fluid portion decanted with sufficient dexterity to prevent it from cooling during the process, and at the same time from injuring the crystals coating the interior of the vessel. The liquid matter should be placed so as to be free from all vibration. The greater the mass of the material, and the more slowly it is cooled, the more voluminous and better defined will be the crystallization.

Crystallization by Sublimation.—Volatile solids, as iodine, camphor, several metallic chlorides and mercurial compounds, arsenic, benzoic acid, iodide of lead, etc., when heated as directed in *sublimation*, yield vapors which, in cooling, take the form of crystals.

Crystallization from Solution.—When it is desired to obtain a substance in crystals it must first be liquefied, or made into a *solution* with an appropriate liquid. If, after making the solution, there be any insoluble residue, it must be separated by *filtration;* and subsequently, if the solution is capable of decolorization by such means, it should be boiled with a small portion of clean bone or ivory black, and again filtered. As it is the almost universal law that heat increases the solvent power of bodies, the solution should generally be made and clarified at the boiling point, so that the excess of matter taken up at the high temperature may separate, on cooling, in the form of crystals. So long as a solution is dilute it yields no crystals; these latter are only formed when the containing liquid is supersaturated; or, in other words, holds more than it can retain; and consequently, in diminishing the quantity of the liquid by *evaporation*, we increase the density of that which remains, and hence, upon cooling, it deposits that excess of the dissolved substance which it only held by virtue of its high temperature. Some instances are so easily soluble, and to such an unlimited extent, that their solutions form crystals immediately upon cooling; others, again, are taken up with such difficulty, even at high heats, unless in large bulks of liquid, that although exposed to prolonged ebullition they require to be evaporated in order to separate what has been dissolved. As the mode of evaporating has an important influence upon the form and size of crystals, we give some hints as to the proper manner of performing it.

If large and well defined crystals are

required, the solution should be subjected to spontaneous evaporation, for the more slow and uniform the concentration the more regular and gradual will be the superposition of material required to make distinct and large crystals. A slight addition of solution of gelatine will, in some instances, it is said, give the crystals the form of plates, as in the case of boracic acid. The solution should be removed from the fire as soon as drops, withdrawn by a glass rod, and deposited upon a watch glass or clean spatula, give small crystals upon cooling. If, however, a very dense crystallization is required, the concentration may be continued until a pellicle forms upon the top, but then the solidified masses are confused and less brilliant. These essays indicate that the liquid is evaporated to a point at which it cannot retain all of its soluble matter. The vessels are then placed aside to cool gradually and uniformly, that the excess may crystallize out of the liquid. The temperature should be regular, for slight variations may alter the form of the crystals.

Bodies equally soluble in cold and hot water, as well as those which are deliquescent, require a prolonged evaporation, as they only crystallize from very dense solutions.

When the liquid is to be converted *wholly* into solid, then the process is termed *granulation*, and is practiced by concentrating it to a syrupy consistency, removing the vessel from the fire and stirring its contents *constantly* until the mass has cooled into granules. This mode is adapted for purifying pearlash and converting it into *sal tartar*, and also for graining brown sugars.

Emulsions and Emulsifying.

To emulsify an oil consists in rendering it capable of mixing with water to form a uniform milky fluid, by the aid of an intervening medium, generally saccharine or mucilaginous.

Milk being the most perfect emulsion obtainable, the mixture of fat which stimulates this compound most closely must likewise be regarded as superior in the degree that these qualities are intensified. To be sure, an artificial emulsion always represents a greater percentage of fat than milk, and its preservation is, therefore, relatively easier than in that obtained from nature; but this fact merely modifies the result, and does not involve the principle. The greater proportion of water in milk also favors decomposition, but on the other hand, the minute, perhaps even molecular, division of the fat globules renders it possible to withstand decomposition longer than an equally dilute artificial emulsion, wherein the oil globules are not so thoroughly disseminated.

We, of course, recognize the fact that milk contains different animal bodies not present in ordinary artificial emulsions, which are prone to decomposition, so that the similarity drawn between the two is based more upon physical characteristics than their presenting any features in common chemically.

But it is this attempt at compromising its principal physical feature—fluidity—with permanency, which makes the preparation of an emulsion so difficult. To so change a fat as to render it miscible with water is a matter of easy execution, but when we attempt to embody the desirable feature of fluidity then we are thwarted by physical laws, and resort to chemical means as a compromise.

Condensed milk is a striking illustration wherein by a change of its physical condition, complete preservation has been attained much more satisfactorily than milk in its natural form could be preserved, even with chemical means. It is for this reason that *consistency* is the most desirable feature to insure the permanence and preservation of any emulsion, natural or artificial.

It is well known that a perfect and permanent emulsion can be made with cod-liver oil and malt extract, owing to the consistency of the preparation solely, as we have attempted to use the same agents represented in malt extract, namely, dextrine and glucose, and discovered that as soon as the consistency was abandoned these agents did not possess any advantage over those usually employed for emulsifying fats. To the albumen in milk has been ascribed the high degree of and most permanent emulsification, and therefore gelatine is employed in artificial emulsions, with not much better success, however, than other agents, when semi-fluid consistency is abandoned.

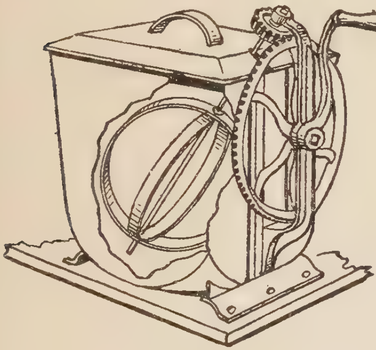
We will now consider what should be used as emulsifying agents, and also such as, while largely used, are not desirable, for obvious reasons.

Unfortunately, the well-worn maxim, so justly applied to most classes of pharmaceutical preparations, "The sacrifice of medicinal value for elegance," has not been lost sight of in the preparation of emulsions. Periodically, different substances from all the different kingdoms of nature have been proposed, enjoyed a

short, fashionable stay, and then been relegated to their well merited oblivion.

The vegetable gums, acacia and tragacanth, have been the longest in use, and the first mentioned of these has probably answered the purpose of a reliable, convenient, and at least innocuous emulsifying agent better than the majority of latter-day substitutes.

The late Prof. Wm. Procter announced the proportion to be used of gum acacia to produce a perfect temporary emulsion. His directions were as follows: "Mix



Emulsifier

intimately, in a perfectly dry mortar, the oil with one-half its weight of powdered acacia; to this add at once one-half as much water as the combined weight of oil and gum, and triturate briskly until the mixture has assumed the color and consistency of a thick cream, which produces a crackling noise when the pestle is moved rapidly around the sides of the mortar." This is the emulsion proper, and to this can be added any amount more of water or other desirable vehicle or medicament to bring the finished preparation up to the quantity prescribed.

If perfectly made, this emulsion will stand any degree of dilution with watery mixtures; in fact, its quality is proved when, by a large addition of water, the oil globules will not separate or aggregate at the top of the liquid.

Practice has demonstrated that the proportion of gum can be varied according to the nature of the oil employed, but the constant relation between the water used for the emulsion proper, and the mixture of oil and gum, must be scrupulously adhered to as insuring infallible results.

Fixed oils rich in gum, *per se*, as copaiba, castor oil, etc., do not require as large an amount of gum as cod-liver oil, while in the case of ethereal oils, for instance, oil of turpentine, an equal amount of gum, or weight for weight, is necessary. To prepare an emulsion from turpentine not unfrequently presents difficulties, and so much the more is this to be guarded against, as it is a powerful remedy, and if presented in a merely mechanical mixture will prove irritating, and perhaps engender serious consequences.

But then, if by careful observance of this method we can obtain a perfect emulsion, what more is desired? Although this emulsion is perfect, it is not permanent, and to circumvent this negative feature is the problem for solution.

While we have not discovered any means or process whereby this problem can be solved, yet we have found agents capable of preventing this separation in a great degree, being guided in their selection by a knowledge of the constituents which are most favorable to this separation and those that are not.

An emulsion should be palpable, and for this reason it is always sought to make it sweet by the introduction of cane sugar or glycerine. These two agents are the cause of the most dissatisfaction with emulsions. Sugar, owing to its affinity for water, and density, favors separation very rapidly, precipitating while the emulsified oil forms a compact, creamy and gradually diminishing stratum at the top of the vessel. Glycerine, probably from the same causes, and its incompatibility with fixed oils, behaves in a similar manner, and for these reasons these otherwise desirable vehicles cannot be represented in an emulsion when permanence is to be obtained.

As no other agents present themselves for fulfilling the sweet object in view, we have been in the habit of preparing emulsions without attempting to make them sweet, and, we believe, without detracting from their palatability, while enhancing their appearance.

Now, then, let us consider what agent will favor the homogeneity of the emulsion; that is, prevent separation or precipitation, bearing in mind that the preparation must not be changed physically or chemically.

Gelatine has been used with some satisfaction, as it retards the separation for a considerable length of time; in fact, it answers the purpose so well that for the extemporaneous preparing of emulsions it leaves nothing to be desired. But in com-

mon with other agents used for this purpose, it gradually loses its power of preserving the homogeneity of an emulsion, and eventually the separation and decomposition, so called, alluded to above, take place.

The proportion of gelatine employed is about 40 gr. to 1 pt. of the emulsion; it should be dissolved in the water, and added at any time of the operation. By increasing this amount so that a jelly is formed of the emulsion, a perfectly permanent and stable preparation is obtained. But this result is obtained because the physical character of the emulsion has been changed—fluidity abandoned for consistency. Unhappily, we cannot take advantage of this condition, and therefore "consistency is not a jewel" pharmaceutically.

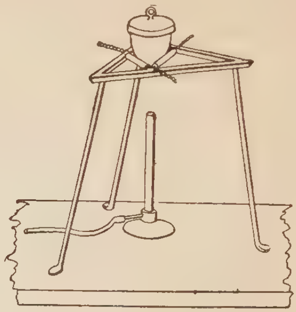
Chemical agents such as change the character of an emulsion by saponifying the oil, have been largely advocated, and to the employment of this class of substances is principally due the elegance and permanence of ready-made emulsions. That this is attained at the sacrifice of medicinal value of the preparation we have no doubt, but medical authorities have also demonstrated it to be a questionable procedure to chemically change the constitution of a fat intended for internal administration by what should be a simple pharmaceutical process—emulsification—and now condemn the use of alkalies with balsams and rosins. Copaiba is no more exhibited with solution of potash, and alkalies are generally conceded as operating to break up the sensitive electronegative principles of rosins, upon which their medicinal value chiefly depends. Animal fat, and especially cod-liver oil, when rendered alkaline, undoubtedly suffers decomposition in those very constituents to which its superior digestibility is due, and thus what has been gained on one hand is more than lost on the other. The saponification which has been produced by the use of the alkali renders the preparation very prone to rancidity if exposed to the air, and even when freshly made it possesses inferior palatability; but then this has been of secondary importance to homogeneity or elegant appearance.

V
IGNITION

Substances frequently require to be ignited to redness, either as the sole process of their preparation, or as a preliminary step to subsequent operations.

Ignition of Filters.

In analyses, the filters containing the insoluble or precipitated substances which are to be estimated are ignited or "burned off," to expel carbonaceous and volatile matters, before being weighed. The im-



Heating Porcelain Crucible

plements for this purpose are porcelain or platinum crucibles, either having their appropriate application.

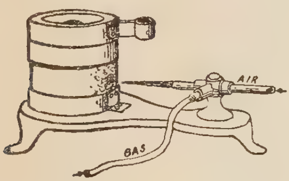
As it is necessary that the filter should be wholly or partially dry, it must be carefully removed from the funnel, so as not to lose a particle of its contents, compressed between the folds of bibulous paper, and, further, dried in a capsule over a sand or water bath, or in a drying stove (desiccation), at a temperature of about 200° F., or less. The dried filter is then to be transferred to the crucible, which has been previously weighed. The transfer must be made without the loss of the least particle, and for this purpose the crucible may be placed upon a sheet of glazed white paper, so that any particles that accidentally fall may be preserved. The filter should be placed in the crucible with its apex upwards, after having been freed as much as possible from the adherent precipitate by gently rubbing the sides together between the thumb and forefinger. The force used for this purpose must not be sufficient to abrade the paper, otherwise the matter will reach the fingers, and a loss thus be occasioned by adherence.

When substances are to be ignited for the determination of their hygroscopic, volatile, or organic matter, the heat of the lamp should be gradually applied without the blast, and, for the former purpose, only to the production of a dull red heat. In these instances, the crucible should be weighed first, so that the loss sustained

by a given weight of its contents during ignition, may be ascertained in one weighing merely by subtracting the weight of the crucible and contents after ignition from the combined weight of the two before the same process. The loss gives the amount of the volatile matter.

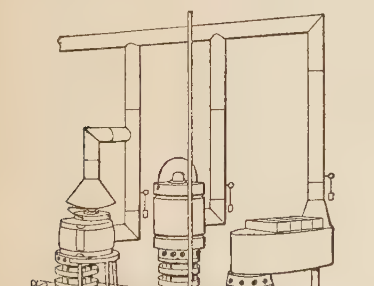
In analyses of coals, the moisture can be determined by heating the crucible in a hot sand bath, or very gently over a low flame. After the loss thus occasioned is determined by weighing, the amount of carbon may be ascertained by subjecting the crucible and contents to a much higher heat.

When the substances are to be exposed to heat, the crucible and contents must



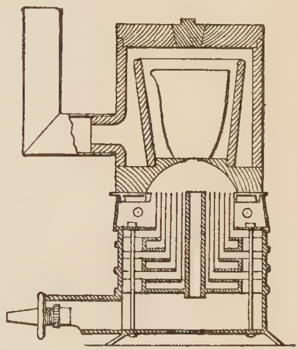
Gas Crucible Furnace with Air Blast.

likewise be weighed separately before ignition. The loss of weight gives the amount of volatile matter driven off. The ignited matter can then be removed from


Assayer's Plant of Gas Furnaces.

the crucible by hot water alone or acidulated.

Scoriae may be removed from platinum crucibles by covering them with a paste of borax and carbonate of soda, heating them to redness, and when cold, dissolving out the saline matter with boiling water. A repetition of the process is necessary to brighten the crucible perfectly if it had been very dirty. One of our engravings represets an assaying plant of gas furnaces as arranged by Walter Lu Brour. The furnace to the right is for roasting, the middle is for crucible fusions, and to the left is one for scorification and cupellation.


Gas Crucible Furnace Without Blast.

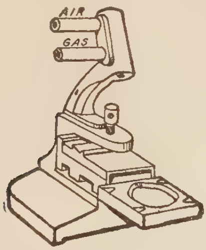
Fusion.

Fusion is a process of liquefying solid bodies by heat without a solvent, such as wax melting. Gas melting arrangements as shown are recommended. With this apparatus a sound 2-oz. ingot of gold or silver can be molded in 2 min. A crucible of molded carbon is supported by a sheet-iron slide or plate which is clamped to an ingot mold by a clamp which swivels in the U-shaped cast-iron stand. The metal to be melted is placed in the crucible, and the flame of the blowpipe directed on it until it is perfectly fused. The whole is then tilted over by means of the upright handle at the back of the mold. The waste heat serves to make the ingot mould hot. No flux should be used with the carbon crucibles.

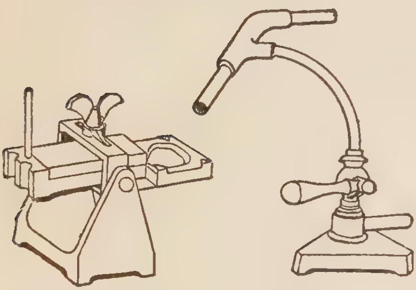
The plate mold will cast an ingot 1⅜ x 1⅜ x 3-16 in. thick; wire mold, 3-16 x 3-16 x 2¾ in. long.

For melting up to 2 oz. of gold or silver rapidly, without the use of a furnace. In this arrangement the two parts of the

ingot mold slide on each other, to enable ingots of any width to be cast, and the blowpipe is part of the rocking stand.



Ingot Casting Arrangement.



Carbon Crucible.

When the metal is melted in the shallow crucible of molded carbon, till the whole apparatus over so as to fill the ingot mold.

Calcination.

The separation (in a dry way) of volatile from fixed matter, by heat, is termed calcination. The process is applicable:

To the expulsion of water from salts, minerals, coals and other substances.

To the expulsion of carbonic acid from certain carbonates.

To the expulsion of arsenic and sulphur from cobalt, nickel and other sulphuretted compounds.

To the expulsion of bituminous matter from coals, and certain minerals and ores.

To the ignition of quartz and silicious minerals to promote their disintegration.

For the purpose of expelling the combined water of argillaceous minerals, and of thus rendering them more obstinate to the solvent action of acids and reagents.

If the substance under process is organic, its calcination in a close vessel by a medium heat usually effects only partial decomposition, the gaseous matter generated escaping through interstices and the fixed components remaining with a portion of unaltered carbon. Performed in this manner, the process takes the name of coking, familiar instances of which are the formation of coke by distilling coal in closed retorts, the manufacture of charcoal from wood, and of bone black from bones.

By increasing the temperature and admitting the air, the whole of the alterable and volatile matter is expelled, the fixed matter remaining as ashes. The process is then styled incineration, and in this way the coke, charcoal and ivory black, obtained as above directed, may be entirely reduced to their incombustible portions or ashes.

Calcination is effected in platinum spoons or crucibles, in delicate experiments, over a spirit lamp; but in large operations a furnace is required, and the containing vessels are crucibles of either metal or earthenware, according to the nature of the substance to be heated, though the latter are often unsuitable for temperatures above a red heat.

When the operation is finished, the crucible should be taken from the fire and allowed to cool gradually. The cover is then to be lifted off and the contents taken out with a spatula, and the portions adhering to the sides removed with a feather.

If the substance undergoing calcination is fusible, it is necessary when quantities are to be ascertained, to weigh both the crucible and contents before ignition, so that the amount of volatile matter driven off may be expressed by the weight lost in heating. Water alone or acidulated, with the aid of heat, generally removes the calcined matter from the crucible.

A body decripitating by heat should be powdered before being subjected to the process of calcination, and the temperature should be raised slowly and gradually, otherwise when the crucible is not covered, a loss may result from the ejection of particles.

To avoid contact with the generated vapors or with the atmosphere, which to some substances act as reducing agents, the crucible should in such cases be covered, and if tightly luted perforated with one or more small holes for the escape of vapor.

Roasting (as the term is generally used) is a kind of calcination to which many ores are submitted before their final reduction to the metallic state, for the

purpose of expelling ingredients which would either delay that process or be injurious to the metal when extracted. In this way water, carbonic acid, sulphur, selenium, arsenic, and sometimes other substances, are driven off from the ores containing them. The term is also applied to other processes, among the most important of which is that of the exposure to heat and air by which metals become altered in composition. Thus, copper becomes oxidized, and antimony and arsenic acidified by union with oxygen.

Roasting is always effected in broad, shallow open vessels, so that the air may have free access; and in order to promote the absorption of oxygen or the escape of the volatile substances, the surface of the body to be heated should be increased by previous pulverization, and it should be constantly stirred during the operation so as to present as many points of contact as possible. The most suitable vessel is a baked earthenware saucer or capsule placed in a muffle or upon the bars of a calcining furnace. Sometimes a crucible is used, and then the position of the vessel in the furnace should be slightly inclined on one side. In either case the vessels should be heated to dull redness previous to receiving their charge.

Deflagration.

That species of roasting termed deflagration is effected by rapidly heating the substance to be oxidized, together with some additional body as an oxidizing agent, as a nitrate or chlorate for instance. The powdered mixture is added portionwise to the crucible previously heated, and maintained at redness during the operation. The vivid and sudden combustion which ensues modifies the composition of the original substance and increases its amount of oxygen at the expense of the addendum. Thus, for instance, sulphuret of arsenic is deflagrated with niter to produce arseniate of potassa, titanium and certain other metals to be transformed into oxides.

Deflagration is also used as a means of detecting the presence of nitric or chloric acids. For this purpose the suspected substance is to be heated with cyanide of potassium, in a small platinum spoon. If deflagration ensues it is a test of the presence of one of them, or a compound of one of them.

The crucibles may be of clay or metal, according to the nature of the substances to be heated. The roasting of substances for the expulsion of organic matter may be effected in platinum vessels, provided the heat is not caried sufficiently high to produce fusion of the substance being roasted.

The heat must, at first, be very gradually applied, and at no time be made great enough to fuse or agglutinate the material, otherwise the process will have to be suspended in order to repulverize the matter. Proper care at the commencement will obviate the necessity of this additional trouble. When the heat has been cautiously raised to redness and all liability of fusion is over, the fire may be urged to the production of a yeilowish red or even white heat, so that the expulsion of volatile matter may be complete.

Roasting operations which disengage deleterious or disagreeable fumes should be carried on in the open air or under a hood, and when the volatile matters are valuable they may be condensed as directed in *Distillation* and *Sublimation.*

Decrepitation.

This frequently occurs and occasions loss by ejections of particles of the mixture, owing to the sudden vaporization of the water of crystallization, which in finding vent scatters the confining substances with a crackling noise. To prevent this loss, the crucible should be loosely covered until decrepitation ceases.

Reduction.

This operation is employed for the separation of metallic bases from any bodies with which they are combined; but is generaly confined to the extraction from an oxide—that being the kind of combination most commonly met with. The combined action of heat and certain reagents is required to effect this result, the temperature varying with the nature of the substance to be reduced.

The most usual reducing agents are charcoal and hydrogen gas. Tallow, oil and rosin are sometimes used, but being easily decomposed they are dissipated before entire reduction has occurred. Sugar and starch are also occasionally employed. We shall, however, confine our remarks to the two principal articles.

Reduction by Charcoal.

Charcoal is used for this purpose in two ways, either in powder and directly mixed with the substance, or as a lining coat to the crucible in which the reduction is accomplished. The first mode is objectionable, because the excess of coal which is required to be used interferes with the agglomeration of the particles

of reduced metal. Whenever it is adopted, the quantity of coal dust to be added, which must be sufficient to transform all the oxygen of the oxide into carbonic acid, can be determined by calculation. This amount is then mixed thoroughly with the oxide previously powdered, and is transferred to a crucible, taking care to place the charge in the center and to cover the contents with a layer of the dust. The whole is then to be subjected to the heat of a furnace, assisted if necessary by a blast. The reduction in this way, the most convenient for large quantities, is rapid and complete, but the metallic residue is often mixed with coal dust.

Incineration.

This is a process of heating organic substances with air until all the carbon is consumed, the product sought being the ash.

Carbonization.

This is a process calling for the heating of organic substances without exposure to the air until all the volatile products are given off and the residue remains as a kind of charcoal. Bone black is a good example.

Sublimation.

When simple compound bodies which are either wholly or in part capable of assuming the aeriform state are subjected to heat, they or their most volatile constituents, upon reaching the required temperature, rise in the form of vapor. If these vapors, in their transit, are intercepted by a surface of a lower temperature, they condense and take a solid or liquid form, according to their nature. If the product is a solid, it is termed *sublimate*, and the process by which it is obtained is *sublimation*. If it is liquid or gas, it takes the name of *distillate*, and the operation which yields it that of *distillation*.

Both of these processes are indispensably useful in chemistry, for they afford the facility of taking advantage of the unequal volatility of bodies for their separation.

As instances of sublimation, we have calomel and corrosive sublimate made by heating equivalent proportions of sulphate of mercury and comon salt; benzoic acid evolved from the gum; pure indigo from the commercial article, and camphor from the crude material. Iodine is sublimed to free it from impurities; biniodide of mercury to convert it into crystals; naphthaline to free it from empyreumatic matter, and succinic acid to separate water.

Specific Gravity.

The specific weight of a substance is its weight in comparison with weights of similar bulks of other substances. This comparative heaviness of solids and liquids is conventionally expressed in relation to water; they are considered as being lighter or heavier than water. Thus, water being regarded as unity = 1, the relative weight, or specific weight, of ether is represented by the figures .720 (it is nearly three-fourths, .750, the weight of water), oil of vitriol by 1.843 (it is nearly twice, 2,000, as heavy as water). The specific weight of substances is, moreover, by generally accepted agreement, the weight of similar volumes at 15° C. (59° F.), except in the case of alcohol and wine, which are at present taken at 15.6° C. (60° F.), to maintain consistency with the United States laws and regulations; for the weight of a definite volume of any substance will vary according to temperature, becoming heavier when cooled and lighter when heated, different bodies (gases excepted) differing in their rate of contraction and expansion. While, then, specific weight—or, conventionally, specific gravity—is truly the comparative weight of equal bulks, the numbers which in America commonly represent specific gravities are the comparative weights of equal bulks at 15° (59° F.), water being taken as unity.

The true weight of the body is its weight in air plus the weight of an equal bulk of air, and minus the weight of a bulk of air equal to the bulk of brass or other weights employed; or, in other words, its weight *in vacuo* uninfluenced by the buoyancy of the air; but such a correction of the weight of a body is seldom necessary, or, indeed, desirable. Density is sometimes improperly regarded as synonymous with special gravity. It is true that the density of a body is in exact proportion to its specific gravity, but the former is more correctly the comparative bulk of equal weights, while specific gravity is the comparative weight of equal bulks.

The standard of comparison for gases was formerly air, but is now usually hydrogen.

Specific Gravity of Solids Lighter than Water.—This is obtained in a manner similar to that for solids heavier than water; but the light body is sunk by help of a piece of heavy metal, the bulk of the water

which the latter displaces being deducted from the bulk displaced by both; the remainder is the weight of a bulk of water eqtual to the bulk of the light body. For instance, a piece of wood weighing 12 grams (or grains) is tied to a piece of metal weighing 22 grams, the loss of weight of the metal in water having been previously found to be 3 grams. The two, weighing 34 grams, are now immersed, and the loss in weight found to be 26 grams. But of this loss 3 grams have been proved to be due to the buoyant action of the water on the lead; the remaining 23, therefore, represent the same effect on the wood; 23 and 12, therefore, represent the weights of equal bulks of water and wood. As 23 are to 12, so is 1 to .5217. Or, shortly, as before, divide the weight in air by the weight of an equal bulk of water; .5217 is the specific gravity of the wood. Another specimen of wood may be found to be three-fourths (.750) the weight of water, and others heavier. Cork varies from .100 to .300.

The specific gravity of a very minute quantity of a heavy or light substance may be ascertained by noting the specific gravitly of a fluid in which it, being insoluble, neither sinks nor swims, or by immersing it in a weighed piece of paraffine whose specific gravity is known, noting the specific gravity of the whole, and deducting the influence of the paraffine.

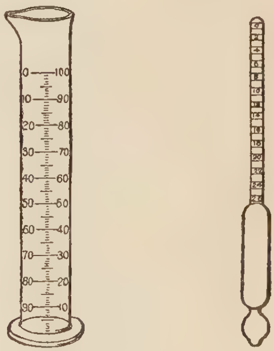
Specific Gravity of Solids in Powder or Small Fragments.—Weigh the particles; place them in a counterpoised specific-gravity bottle of known capacity, and fill up wtih water, taking care that the substance is thoroughly wetted; again weigh. From the combined weights of water and substance subtract amount due to the substance; the residue is the weight of water. Subtract this weight of water from the quantity which the bottle normally contains; the residue is the amount of water displaced by the substance. Having thus obtained the weights of equal bulks of water and substance, a rule-of-three sum shows the relation of the weight of the substance to 1 part of water—the specific gravity.

Or suspend a cup, a short tube, or bucket from a shortened balance-pan; immerse in water; counterpoise; place the weighed powder in the cup, and proceed as directed for taking the specific gravity of a solid in a mass.

Specific Gravity of Solids Soluble in Water.—Weigh a piece of sugar, or other substance soluble in water; suspend it from a balance in the usual manner, and weigh it in turpentine, benzol or petroleum, the specific gravity of which is known or has been previously determined; the loss in weight is the weight of an equal bulk of the turpentine. Ascertain the weight of an equal bulk of water by calculation:

As is the specific gravity of turpentine to the specific gravity of water, so is the observed bulk of turpentine to an equal bulk of water.

The exact weights of equal bulks of sugar and water being obtained, the weight of a bulk of sugar corresponding to 1.000 of water is shown by a rule-of-three sum; in other words, divide the weight of sugar by that of the equal bulk of water; the quotient is the specific gravity of sugar. The stated specific gravity of the sugar ranges from 1.590 to 1.607.



Hydrometers and Jar

Hydrometers.—The specific gravity of liquids may be ascertained without scales and weights, by means of a hydrometer, an instrument usually of glass, having a graduated stem, and bulb or bulbs at the lower part. The specific gravity of a liquid is indicated by the depth to which the hydrometer sinks in the liquid, the zero of the scale marking the depth to which it sinks in pure water. Hydrometers require a considerable quantity of liquid to fairly float them, and specific gravities observed with them are less delicate and trustworthy than those obtained by the balance; nevertheless, they are exceedingly useful for many practical purposes where the employment of a delicate balance would be inadmissible.

Hydrometers are of two kinds: First, those which are always immersed in the

same depth in still water and the liquid to be tried, small weights being used for the purpose, as in Fahrenheit's and Nicholson's hydrometers; and second, those which are suffered to rise or sink freely in the liquid, as in Syke's and Baumé's. In both cases a correction must be made for any variation in temperature.

In conducting technical experiments, the hydrometer will often be found of great use, even to those who are not chemists. The Baumé instrument seems to be falling into disuse, a hydrometer having a graduated scale in which the graduations represent the specific gravity, taking its place. A hydrometer jar and two specific gravity scale hydrometers should be used, one for liquids heavier than water, and one for liquids lighter than water. For special purposes, or if the equipment of the laboratory is large, a considerable number of hydrometers may be provided. When constructed for special purposes they often have special names. In the catalogue of a prominent manufacturer of chemical apparatus and materials we find the following special hydrometers for special purposes. The prices run from 75 cents to $2.00, although some special types cost more, and some are only sold in sets. These special hydrometers are for testing the following substances: Alcohol, alkali, ammonia, bark (tannometer), battery fluid, beer, beer and wort, benzine, blood, chlorine, cider, coal oil, ether, gasoline, glycerine, milk (lactometer), naphtha; oil, salt solution (salimeter), silver solution, sugar, vinegar, wine and must. If the liquid is too warm, the hydrometer jar containing it should be cooled to the proper temperature; if the temperature has fallen too low, the hydrometer jar can be slightly warmed with the hand. Many of the hydrometers found in the older books have either dropped out of use, or are rarely used in this country by chemists. The Pralles hydrometer is largely used by distillers in this country, and by the Government for making alcoholic determinations. Twaddell's hydrometer is very often employed in tanneries and other technical works, especially in England. If work in specific gravity is to be performed, a specific gravity balance is recommended. The tables of specific gravity will be found in the chapter on WEIGHTS AND MEASURES. Tables of specific gravity, and the method of using the same, are presented herewith.

Thermometer Scales.

Much annoyance is caused by the great difference of thermometer scales in use in the different civilized countries. The scale of Reaumur prevails in Germany. As is well known, he divides the space between the freezing and boiling points into 80°. France uses that of Celsius, who graduated his scale on the decimal system. The most peculiar scale of all, however, is that of Fahrenheit, a renowned German physicist, who in 1714 or 1715, composed his scale, having ascertained that water can be cooled under the freezing point without congealing. He therefore did not take the congealing point of water, but composed a mixture of equal parts of snow and sal ammoniac, about — 14° R. The conversion of any one of these scales to another is very simple, and easily made. To change a temperature, as given by Fahrenheit's scale, into the same as given by the centigrade scale, subtract 32° from Fahrenheit's degrees, and multiply the remainder by 5-9. The product will be the temperature in centigrade degrees.

To change from Fahrenheit's to Reaumur's scale, subtract 32° from Fahrenheit's degrees, and multiply the remainder by 4-9. The product will be the temperature in Reaumur's degrees.

To change the temperature, as given by the centigrade scale, into the same as given by Fahrenheit, multiply the centigrade degrees by 9-5 and add 32° to the product. The sum will be the temperature by Fahrenheit's scale.

To change from Reaumur's to Fahrenheit's scale, multiply the degrees on Reaumur's scale by 9-4 and add 32° to the product. The sum will be the temperature by Fahrenheit's scale.

For those who wish to save themselves the trouble we have calculated the following comparative table.

 (Thermometer Scales)

COMPARATIVE SCALES OF THERMOMETER.

C.	R.	F.	C.	R.	F.	C.	R.	F.
-30	-24.0	-22.0	14	11.2	57.2	58	46.4	136.4
-29	-23.2	-20.2	15	12.0	59.0	59	47.2	138.2
-28	-22.4	-18.4	16	12.8	60.8	60	48.0	140.0
-27	-21.6	-16.6	17	13.6	62.6	61	48.8	141.8
-26	-20.8	-14.8	18	14.4	64.4	62	49.6	143.6
-25	-20.0	-13.0	19	15.2	66.2	63	50.4	145.4
-24	-19.2	-11.2	20	16.0	68.0	64	51.2	147.2
-23	-18.4	-9.4	21	16.8	69.8	65	52.0	149.0
-22	-17.6	-7.6	22	17.6	71.6	66	52.8	150.8
-21	-16.8	-5.8	23	18.4	73.4	67	53.6	152.6
-20	-16.0	-4.0	24	19.2	75.2	68	54.4	154.4
-19	-15.2	-2.2	25	20.0	77.0	69	55.2	156.2
-18	-14.4	-0.4	26	20.8	78.8	70	56.0	158.0
-17	-13.6	1.4	27	21.6	80.6	71	56.8	159.8
-16	-12.8	3.2	28	22.4	82.4	72	57.6	161.6
-15	-12.0	5.0	29	23.2	84.2	73	58.4	163.4
-14	-11.2	6.8	30	24.0	86.0	74	59.2	165.2
-13	-10.4	8.6	31	24.8	87.8	75	60.0	167.0
-12	-9.6	10.4	32	25.6	89.6	76	60.8	168.8
-11	-8.8	12.2	33	26.4	91.4	77	61.6	170.6
-10	-8.0	14.0	34	27.2	93.2	78	62.4	172.4
-9	-7.2	15.8	35	28.0	95.0	79	63.2	174.2
-8	-6.4	17.6	36	28.8	96.8	80	64.0	176.0
-7	-5.6	19.4	37	29.6	98.6	81	64.8	177.8
-6	-4.8	21.2	38	30.4	100.4	82	65.6	179.6
-5	-4.0	23.0	39	31.2	102.2	83	66.4	181.4
-4	-3.2	24.8	40	32.0	104.0	84	67.2	183.2
-3	-2.4	26.6	41	32.8	105.8	85	68.0	185.0
-2	-1.6	28.4	42	33.6	107.6	86	68.8	186.8
-1	-0.8	30.2	43	34.4	109.4	87	69.6	188.6
0	0.0	32.0	44	35.2	111.2	88	70.4	190.4
1	0.8	33.8	45	36.0	113.0	89	71.2	192.2
2	1.6	35.6	46	36.8	114.8	90	72.0	194.0
3	2.4	37.4	47	37.6	116.6	91	72.8	195.8
4	3.2	39.2	48	38.4	118.4	92	73.6	197.6
5	4.0	41.0	49	39.2	120.2	93	74.4	199.4
6	4.8	42.8	50	40.0	122.0	94	75.2	201.2
7	5.6	44.6	51	40.8	123.8	95	76.0	203.0
8	6.4	46.4	52	41.6	125.6	96	76.8	204.8
9	7.2	48.2	53	42.4	127.4	97	77.6	206.6
10	8.0	50.0	54	43.2	129.2	98	78.4	208.4
11	8.8	51.8	55	44.0	131.5	99	79.2	210.2
12	9.6	53.6	56	44.8	132.8	100	80.0	212.0
13	10.4	55.4	57	45.6	134.6			

To change the temperature as given by the centigrade scale into the same as given by Fahrenheit, multiply the centigrade degrees by 9-5 and add 32 deg. to the product. The sum will be the temperature by Fahrenheit's scale.

To change from Reaumur's to Fahrenheit's scale, multiply the degrees on Reaumur's scale by 9-4 and add 32 deg. to the product. The sum will be the temperature by Fahrenheit's scale.

For those who wish to save themselves the trouble we have calculated the preceding comparative table.

PART III.

Technical Formulas
for the
Shop and Home Labratory

CHAPTER I.

ALLOYS AND AMALGAMS

This subject is indexed, and the reader should consult the Index in all cases. SOLDERS form the subject of a special chapter.

BRIEF SCHEME OF CLASSIFICATION

GENERAL INFORMATION ON ALLOYS
- ALUMINUM ALLOYS
- BISMUTH AND CADMIUM ALLOYS
  - FUSIBLE ALLOYS
- COPPER ALLOYS
  - GERMAN SILVER
  - BELL METAL
  - BRONZE
  - GUN METAL
  - SPECULUM METALS
  - BEARING METALS
  - BRASS
- GOLD ALLOYS
  - IMITATION GOLD
- IRON ALLOYS
- LEAD ALLOYS
- MANGANESE ALLOYS
- PLATINUM ALLOYS
- SILVER ALLOYS
  - SILVER SUBSTITUTES
- TIN ALLOYS
  - BEARING METALS
  - BABBITT METAL
  - WHITE METAL
  - BRITANNIA METAL
  - TIN SUBSTITUTES
  - TYPE METAL
- TUNGSTEN ALLOYS
- ZINC ALLOYS
- AMALGAMS

GENERAL INFORMATION ON ALLOYS

Nature of Alloys.—When two or more metals are caused permanently to unite, the resulting mixture is termed an alloy. When mercury is an essential constituent, the mixture is termed an amalgam. The general method of effecting combination is by the agency of heat, but with certain soft metals true alloys may be formed by subjecting the constituents to considerable pressure, even at the ordinary temperature. Alloys such as those briefly referred to were doubtless first discovered by the metallurgical treatment of mixed ores, from the simultaneous reduction of which alloys would be formed; or, in some cases, as in ores of gold and silver, naturally formed alloys would be obtained by a simple melting process. The direct preparation of alloys by the simple melting together of the constituent metals has been enormously developed in modern times, and the attention which mixed metals are now receiving by chemists is far greater than in any period of history. Comparatively few of the metals possess properties such as render them suitable to be employed alone by the manufacturer; but most of them have important applications in the form of alloys. Even among the metals which can be used independently, it is often found expedient to add portions of other metals to improve or otherwise modify their physical properties. Thus gold is hardened, and made to resist wear and tear, as well as to lower its cost, by the addition of copper; silver is likewise hardened by alloying it with copper; and the bronze coinage is formed of an alloy of copper, zinc and tin for similar reasons.

Alloys generally possess characteristics unshared by their component metals. Thus, copper and zinc form brass, which has a different density, hardness and color from either of its constituents.

The specific gravity of alloys is never

the arithmetical mean of that of their constituents, as commonly taught; and in many cases considerable condensation or expansion occurs. When there is a strong affinity between two metals, the density of their alloy is generally greater than the calculated mean, and *vice versa,* as may be seen in the following list:

Alloys the Density of which is Greater than the Mean of their Constituents.—Gold and zinc; gold and tin; gold and bismuth; gold and antimony; gold and cobalt; silver and zinc; silver and tin; silver and bismuth; silver and antimony; copper and zinc; copper and tin; copper and palladium; copper and bismuth; lead and antimony; platinum and molybdenum; palladium and bismuth.

Alloys the Density of which is Less than the Mean of their Constituents.—Gold and silver; gold and iron; gold and lead; gold and copper; gold and iridium; gold and nickel; silver and copper; iron and bismuth; iron and antimony; iron and lead.

Preparation and Properties of Alloys.—The mode of procedure in the production of any alloy will be largely influenced by the nature of the metals to be operated upon. Some metals are volatile, and readily pass off as vapor when heated a few degrees above their melting points. Others have little tendency to vaporize, and may be raised to high temperatures without sensible volatilization. When a volatile metal has to be alloyed with a non-volatile metal, and the fusing points of both are approximately the same, combination can be most readily effected by mixing the constituents and melting them together in the same crucible or furnace. This is, however, seldom the case, and, as a general rule, the components of an alloy, one or all of which are volatile, have widely divergent melting points, and then it is requisite for the most refractory constituent to be melted first, and for the others to be added in the solid state. Again, an alloy may contain one or more fixed metals and a volatile one, in which case the more volatile metal is added to the crucible after the fixed metal or metals have been fused, and raised to a temperature necessary to melt the volatile constituent immediately it is introduced, so that combination may be effected before any serious loss, due to vaporization, has occurred. Union between the components of an alloy is more perfectly secured by agitation of the contents with a stirring-rod, the most effective in many cases being a wooden or carbon rod, which promotes admixture without the introduction of any substance likely to contaminate the mixture and modify its properties.

A thing to be guarded against in the melting of all base metals, or alloys containing base metals as essential constituents, is oxidation. Various plans are adopted to avoid loss of metal and injury to the alloy from this cause. The most common one is to cover the metals with carbon, which not only excludes the air admitted to the furnace, but tends to absorb any oxygen liberated from the metals during fusion. Thus, as long as the mixture is covered with carbon, the carbonic oxide formed effectually shields it from oxidation. In the method already referred to of stirring metals with a carbon rod to promote mixture, the same gas, carbonic oxide, is formed, and thus the rod not only promotes union by mechanical agitation, but generates a gas which protects the metals in a great measure from oxidation. In some cases this is not admissible, as commercial metals are impure, and it may be advisable to admit sufficient oxygen, either from the air or by means of a special oxidizing agent, added along with the flux, to convert the impurities into oxides, which do not alloy with the metals, but either enter into combination with the flux to form a slag, or rise to the surface as dross or scum. In most cases it is advisable that the covering body should not exert any influence on the metals beneath.

Some manufacturers are in the habit of throwing fat and rosin on the heated metals before fusion. These are decomposed by heat, liberating gases, and when well stirred with the molten metal promote combination by the mechanical agitation imparted by their escape. They also act chemically in removing oxygen, by the union of that element with the carbon and hydrogen set free. When the evolution of gas has ceased a quantity of carbon remains in a finely divided state, which covers the metals and protects them from oxidation.

Borax is sometimes used to exclude the air, but it is much more costly than carbon, and when it is not required as a flux its employment is accompanied with some evils. Now, borax is composed of the base soda in combination with boric acid, which is only partly saturated with the soda, and the excess of acid unites with any metallic oxide present, forming double borates of a glassy nature. Commercial borax is often very impure, and

is adulterated with common salt and alum; these impurities are injurious to many metals. Sodium chloride, or common salt, is also employed for preserving molten metals from oxidation, and also to moderate the action of bodies which cause violent ebullition. Glass is frequently used for a similar purpose, and, next to carbon, is the least injurious to metals. It is a mixture of silicates, which easily fuses at high temperatures, forming compounds with lime or other bases, so that it acts almost as beneficially as borax when such a flux is required. Window glass or green bottle glass is the most useful, but flint glass, which contains much oxide of lead, would be detrimental in many cases.

It is a well-known fact that the character of many alloys is altered by repeated remelting, and that the scrap obtained in working cannot be used again without the addition of a certain quantity of new metal. A given mixture may be employed for the formation of an alloy, which is highly malleable, ductile, and tenacious, and the scrap from the same alloy, when remelted, may be brittle and unworkable; but when a suitable quantity of new metal is added, the combination may form an alloy even superior to the original one with regard to its good working properties. It is to the advantage of the manufacturer, as regards economy, to use as much scrap as possible in alloying, and the quantity thus employed varies from one-third to two-thirds of the weight of the charge. Of course, in using old metal, many more impurities are liable to be introduced than with new metal, and although the same impurities may exist in the new metal, the quantities may be insufficient to produce a deteriorating effect, but when augmented from old metal may then rise to such proportions as to entirely alter the physical properties of the alloy. The presence of notable quantities of foreign matter is generally exhibited by increased hardness and a modification of the structure, as seen on a freshly fractured surface.

In regard to annealing, five laws are formulated as the result of experiments: (1) Annealing is never instantaneous; its effects, rapid at first, become more and more slow, and the softening tends toward a limit for each temperature; (2) this limit is lower, and is attained more rapidly as the annealing temperature is raised; (3) above a certain temperature annealing is complete, and a further increase of temperature does not diminish the strength, but a crystallization due to annealing occurs, and increases with the time of annealing, ultimately reducing the tensile strength and elongation to those of the cast metal; (4) the presence of impurities retards the action of annealing, and demands a higher temperature for its completion; (5) the crystallization from annealing is due to the presence of impurities which have lower fusing points than the metal itself, or which form compounds which have those properties.

The purposes for which alloys are required are endless. Some are required to possess great malleability, for others hardness is the chief requisite; others, again, must possess a high degree of elasticity, while some are useful on account of their low melting point, etc. These different demands can only be satisfied by uniting suitable metals in different proportions.

The number of simple metals is very limited, but they may be united in various proportions, forming an endless variety of modifications; and since every alloy may be looked upon as a new metal, from the fact of its properties differing from those of its constituents, we have at command the necessary material for producing metals suitable for every requirement for which metallic matter is desirable. The action of metals upon each other is widely divergent; sometimes one metal may be added to another in quantity without seriously altering its working properties; in other cases a minute quantity of the second metal will altogether change the character of the first metal; so that in alloying, it by no means follows, because one metal may be freely added, that another, even of a similar nature, may be as liberally introduced. The man who aspires to the formation of new alloys, or who wishes to produce metals suitable for different requirements, as circumstances arise, must be well acquainted with the nature and properties of the simple metals in order to successfully accomplish his object; and although a knowledge of the components is not sufficient of itself, it is of immense advantage in assisting the operator who combines practical experience in mixing metals with this theoretical knowledge.

In chemical combinations it is a well-known fact that elements always combine with other elements in definite proportions by weight, termed atomic weight, producing compounds of fixed and decided properties, so that the same compounds

can be always relied upon to contain the same elements, united in the same proportions. The same law applies to the union of two metals, when such metals are chemically combined, and the same alloy will always have properties identically the same, however it may be tested. Several experimenters have directed their attention to the mixing of metals according to their atomic weights, so as to obtain alloys of determined characteristic properties, but up to the present time the number of such combinations of a useful character is very limited. They are by no means the ones most suited to the wants and requirements of industry. There is always one indispensable item, from the manufacturer's point of view, which the chemist is not concerned with—that is, the cost of production—and however nicely atomic proportions would suit the requirements of a given alloy, such an alloy would, in most cases, be useless unless the cost was consistent with the market value. The question, then, of cost must have consideration, and the proportions must, if possible, be made to fit in with commercial necessities. With regard to copper alloys, such as brass and bronze, the combinations which best exhibit the characters of chemical compounds are hard and brittle, and as copper alloys are much more widely used than any other, there is little inducement to encourage metallurgists to endeavor to alloy copper and zinc, or copper and tin, in atomic proportions, since malleability and tenacity are the properties most desired in these alloys. Again, color is the chief desideratum in many alloys, and this cannot be always obtained by mixing in atomic proportions, especially as it often happens that a very small addition of one of the constituents will alter the shade of color so as to produce what is required.

When it is desirable to add a nonmetallic element to a metal or alloy, for the purpose of bringing about a certain result, very much greater care is generally required in apportioning the quantity to be added than with a metal, as nonmetals combine much more actively with metals than the metals do with each other, and a very small quantity of a non-metal will suffice to alter the properties of a metal alloy. It is very surprising to note how, in some instances, a mere trace of another element will alter the properties of a metal. For example, 1-2000 of carbon added to iron will convert it into mild steel; 1-1000 of phosphorous makes copper hot-short; 1-2000 part of tellurium in bismuth makes it minutely crystalline; 1-1000 part of bismuth in copper renders it exceedingly bad in quality for certain purposes.

Fusibility.—Some metals are almost infusible, and when heated to the highest heat in a crucible they refuse to melt and become fluid; but any metal can be melted by combination with more fusible metals. Thus platinum, which is infusible with any ordinary heat, can be fused readily when combined with zinc, tin or arsenic. This metal, by combination with arsenic, is rendered so fluid that it may be cast into any desired shape, and the arsenic may then be evaporated by a mild heat, leaving the platinum. Nickel, which barely fuses alone, will enter into combination with copper, forming German silver, an alloy that is more fusible than nickel and less fusible than copper. The less fusible metals, when fused in contact with the more fusible metals, seem to dissolve in the fusible metals; rather than melt, the surface of the metal is gradually washed down, until the entire mass is dissolved or liquefied, and reduced to the state of alloy.

Following are the melting points of the elements employed in alloys:

	Degrees Cent.
Aluminum	654.5
Antimony	629.5
Arsenic	450
Bismuth	268.3
Cadmium	320
Copper	1080.5
Gold	1061.7
Iron	1550-1600
Lead	330- 335
Magnesium	632.7
Manganese	1800-1900
Mercury	39.4
Nickel	1400-1450
Phosphorus	44
Platinum	1775
Silicon	1100-1300
Silver	960.5
Sulphur	114.5
Tellurium	282
Tin	231.68
Zinc	419

The following is a table of the proportions of the various metals in the alloys most commonly employed in the arts and manufactures. The term "parts" means parts by weight. The abbreviations are: Cu, copper; Zn, zinc; Sn, tin; Pb, lead; Sb, antimony; P, phosphorus; As, arsenic; Ni, nickel.

Description.	Cu.	Zn.	Sn.	Pb.	Sb.	P.	As.	Ni.
1. Metal for frictional parts of locomotives (extremely hard)	87	5	8	..	..	..	..	..
2. Bearings of carriages	97	3	..	..	..	..	..	..
3. Bearings of driving wheels, also for steam engine whistles, giving a clear sound	80	2	18	..	..	..	..	..
4. Steam engine whistles giving a deep sound	81	2	17	..	..	..	..	..
5. Cross heads of connecting rods	82	2	16	..	..	..	..	..
6. Cylinders of pumps, valve boxes and taps	88	2	10	..	..	..	..	..
7. Eccentric collars	84	2	14	..	..	..	..	..
8. Bearings of axles and trunnions; eccentric collars	84	2	14	..	..	..	..	..
	85	2	13	..	..	..	..	..
	84	7	9	..	..	..	..	..
	68	4	28	..	..	..	..	..
9. Pistons of locomotives	88	9	3	..	..	..	..	..
	84	8.4	2.9	4.7	..	..	..	..
10. Axle boxes	88	2	10	..	..	..	..	..
11. Mathematical instruments, arms of balances	90	2	8	..	..	..	..	..
12. Machinery, bearings, etc	67	..	14	19	..	..	..	..
13. Steam engine whistles	30	..	..	..	2	..	..	..
14. Metal to withstand friction (Stephenson)	79	5	8	8	..	..	..	..
15. Rivets	64	24.6	3	9	..	..	..	..
16. Metal for coffins	15	..	40	45	..	..	..	..
17. Metal to withstand friction	2	..	72	..	26	..	..	..
18. Cylinders of pumps	7	72	21	..	..	..	..	..
19. Metal for bearings of locomotives	2	..	90	..	8	..	..	..
20. White brittle metal (for buttons, etc.)	10	6	20	..	64	..	..	..
21. Imitation silver	64	..	3	..	..	..	..	..
22. Pinchbeck	5	1	..	..	..	..	..	..
23. Tombac	16	1	1	..	..	..	..	..
24. Red tombac	10	1	..	..	..	..	..	..
25. Specially adapted for bearings	83	..	15.5	..	1.5	..	..	..
26. For bearings and valves	83.25	..	7	9	..	0.75	..	..
27. Electrotype "backing metal"	..	..	4	91	5	..	..	..
28. Stereotype metal for paper process	..	..	..	88	12	..	..	..
29. " " " plaster process	..	..	..	82	18	..	..	..
30. Bullet metal	..	..	..	92	..	..	2	..
31. Malleable brass plate	67	33	..	0.5	..	..	..	..
32. Pin wire	67	33	0.5	0.5	..	..	..	..
33. Jemmapes brass	64.6	33.7	0.2	1.5	..	..	..	..
34. Similor for gilding	92.7	4.6	2.7	..	..	..	..	..
35. Maillechort for rolling	60	20	..	..	..	..	..	20
36. " first quality	8	3	..	..	..	..	..	4
37. White similor	7	..	..	..	..	..	0.5	..
38. For stopcock seats	..	..	86	..	14	..	..	..
39. " " plugs	..	..	80	..	20	..	..	..
40. For keys of flutes, etc	..	..	..	20	40	..	..	..
41. Hard tin	..	..	1	..	0.5	..	..	..
42. White tombac	75	..	25	..	..	..	..	..
43. Vogel's alloy for polishing steel	8	1	2	1	..	..	..	..
44. Rompel's anti-friction metal	62	10	10	18	..	..	..	..
45. Arguzoid, a tough alloy superior to brass	56	23	4	3.5	..	..	..	13.5

ALUMINUM

General Remarks.—Aluminum unites readily with all the common metals except lead. The useful alloys of aluminum so far found may be divided into two classes: the one, of aluminum with not more than 35% of other metals; and the other, of metals containing not over 15% aluminum. In the one case the metals impart hardness and other useful qualities to the aluminum; and in the other the aluminum adds useful qualities to the metals with which it is alloyed.

Alkali Metals

Because of the ease with which these alloys are decomposed, especially when subjected to water or moist air, none of

them can be considered in any way advantageous; in fact, alloys of metallic sodium and potassium with aluminum are the *bête noir* of the metallurgy of aluminum, just as sulphur and phosphorus are feared in the metallurgy of steel.

Copper

Copper Aluminum.—1.—Aluminum is a metal whose properties are very materially influenced by a proportionately small addition of copper. Alloys of 99% of aluminum and 1% of copper are hard, brittle and bluish in color; 95% of aluminum and 5% of copper gives an alloy which can be hammered, but with 10% of copper the metal can no longer be worked. With 80% and upward of copper are obtained alloys of a beautiful yellow color. The 10% alloys are of a pure golden yellow color; with 5% of aluminum they are reddish yellow, like gold heavily alloyed with copper; and a 2% mixture is of an almost pure copper red. As the proportion of copper increases the brittleness is diminished, and alloys containing 10% and less of aluminum can be used for industrial purposes, the best consisting of 90% of copper and 10% of aluminum. The useful copper alloys with aluminum can be divided into two classes—the one containing less than 11% of aluminum and the other containing less than 15% of copper. The first class is best known as "aluminum bronze."

Aluminum Copper.—2.—The second class of copper-aluminum alloys embraces the aluminum casting alloys most applicable for general purposes. When aluminum is alloyed with from 7 to 10% of copper a tough alloy is secured, the tensile strength of which will vary from 15,000 to 20,000 lb. per square inch. This alloy has proved itself especially adaptable to automobile work and to those castings submitted to severe shocks and stresses. Because of the nature of its constituents, an alloy of the above, or of similar composition, is not so liable to be "burnt" in the foundry as an alloy made up of more volatile constituents. The remainder of the range of copper-aluminum alloys, from 20% of copper up to over 85%, give crystalline and brittle grayish-white alloys of no use in the arts. After 80% of copper is reached the distinctly red color of the copper begins to show itself.

Gold

Prof. W. C. Roberts-Austen has discovered a beautiful alloy, composed of 78 parts of gold and 22 parts of aluminum, which has a rich purple color.

Iron

Aluminum combines with iron in all proportions. Few of the alloys, however, have yet proved of value, except those of small percentages of aluminum with steel, cast iron and wrought iron.

Cast Iron.—In cast iron, from 1 to 2 lb. of aluminum per ton is put into the metal as it is being poured from the cupola or melting furnace. To soft gray No. 1 foundry iron it is doubtful if the metal does much good, except, perhaps, in the way of keeping the metal melted for a longer time; but where difficult castings are to be made, where much loss is occasioned by defective castings, or where the iron will not flow well or give sound and strong castings, the aluminum certainly in many cases allows better work to be done, and stronger and sounder castings to be made, having a closer grain, and hence much easier tooled. The tendency of the aluminum is to change combined carbon to graphitic, and it lessens the tendency of the metal to chill. Aluminum in proportions of 2% and over materially decreases the shrinkage of cast iron.

Ferro-Aluminum.—This is the trade name given to alloys of from 5 to 10, or even 20% of aluminum, added to iron, These alloys vary in quality, occasioned by the grade of steel or iron used in making them.

Steel.—The amount of aluminum used is small, and, to give the best results, varies with the grade of steel, amount of occluded gases, temperature of molten metal, etc. Aluminum is usually added in proportions of from ⅛ to ¾ lb. to 1 ton of steel. The aluminum is added either to the metal in the ladle, or, in the case of steel castings, with more economy of aluminum, to the metal as it is being poured into the ingot molds.

Manganese

Manganese is one of the best hardeners of aluminum.

Nickel

1.—This alloy, with from 2 to 5% of the combined alloying metals, is very satisfactory for rolling or hammering. By larger proportions, of 7 to 9%, a good casting alloy is produced.

2.—Two new alloys for jewelry consist of: (1) Nickel, 20 parts; with aluminum, 8 parts. (2) Nickel, 40 parts; sil-

ver, 10 parts; aluminum, 30 parts; tin, 20 parts.

Silver

1.—The addition of a few per cent. of silver to aluminum, to harden, whiten and strengthen the metal, gives a material especially adaptable for many fine instruments and tools, and for electrical apparatus, where the work upon the tool, and its convenience, are of more consequence than the increased price due to the addition of the silver. Silver lowers the melting point of aluminum and gives a metal susceptible of taking a good polish and making fine castings.

2.—Aluminum, 3 parts; silver, 1 part. This alloy is very easy to work.

Tin

1.—Tin has been alloyed with aluminum in proportions of from 1 to 15% of tin, giving added strength and rigidity to heavy castings, as well as sharpness of outline, with a decrease in the shrinkage of the metal. The alloys of aluminum and tin are rather brittle, however, and although small proportions of tin, in certain casting alloys, have been advantageously used to decrease the shrinkage, on account of the comparative cost and brittleness of the tin alloys, they are not generally used.

2.—Aluminum, 100 parts; tin, 10 parts.

3.—Aluminum, 90%; tin, 10%.

Zinc

Like copper alloys, the zinc alloys can be divided into two classes: (1) Those containing a relatively small amount of aluminum. (2) Those containing less than 35% of zinc. Zinc produces the strongest alloys with aluminum, the strength being still further increased by the addition of small amounts of other suitable metals. The tensile strength of the strongest of the zinc alloys frequently runs as high as 30,000 to 35,000 lb. per square inch. These high zinc alloys are brittle, however, and are more liable to "draw" in heavy parts or lugs than are the copper alloys. This can, in most cases, be overcome by suitable gating, placing of chills and risers. Zinc alloys also possess the danger of having the zinc burned out in melting, thus producing a weaker casting. With careful work, however, this class of alloys gives as good satisfaction as copper alloys in respect to hardness, ease of machining, and use in small parts not subject to severe shock. For forging, few metals excel an aluminum-zinc alloy containing from 10 to 15% of zinc. This alloy is tough, flows well under the forging dies, and produces a finished product that is solid, easily machined, and remarkably strong per unit of area.

Zinc is used as a cheap and very efficient hardener in aluminum castings, for such purposes as sewing-machine frames, etc. Proportions up to 30% of zinc with aluminum are successfully used. An alloy of about 15% of zinc, 2% of tin, 2% of copper, ½% each of manganese and iron, and 80% aluminum, has special advantages. The following alloys are strong, and meet all usual requirements:

	Al.	Zn.	Cu.	Sn.
For wire or sheet.....	28	5	..	..
For tubes	13	6	8	2
With good close grain.	20	10	..	..
With good open grain.	18	6	..	..

BISMUTH AND CADMIUM ALLOYS

Bismuth Bronze

1.—A metallic alloy, which the inventor calls bismuth bronze, was introduced by Webster, as specially suitable for use in sea water, for telegraph and music wires, and for domestic articles. The composition varies slightly with the purpose for which the bronze is to be used, but in all cases the proportion of bismuth is very small. For a hard alloy he takes 1 part of bismuth and 16 parts of tin, and, having melted them, mixes them thoroughly as a separate or preliminary alloy. For a hard bismuth bronze he then takes 69 parts of copper, 21 parts of spelter, 9 parts of nickel and 1 part of the bismuth-tin alloy. The metals are melted in a furnace or crucible, thoroughly mixed, and run into molds for future use. This bronze is hard, tough and sonorous; it may be used in the manufacture of screw-propeller blades, shafts, tubes, and other appliances employed partially or constantly in sea water, being especially suited to withstand the destructive action of salt water.

Fusible Alloys

Under the name, fusible metal, or fusible alloy, is understood a mixture of metals which becomes liquid at temperatures at or below the boiling point of water.

1.—D'Arcet's.—Bismuth, 8 parts; lead, 5 parts; tin, 3 parts. This melts below 212° F.

2.—Walker's.—Bismuth, 8 parts; tin, 4 parts; lead, 5 parts; antimony, 1 part. The metals should be repeatedly melted and poured into drops until they can be

well mixed, previous to fusing them together.

3.—Onion's.—Lead, 3 parts; tin, 2 parts; bismuth, 5 parts. Melts at 197° F.

4.—If to the latter, after removing it from the fire, 1 part of warm quicksilver be added, it will remain liquid at 170° F., and become a firm solid only at 140° F.

Table of Fusible Alloys.

Bismuth	Lead	Tin	Degrees F.	Bismuth	Lead	Tin	Degrees F.
8	5	3	202	8	16	24	316
8	6	3	208	8	18	24	312
8	8	3	226	8	20	24	310
8	8	4	236	8	22	24	308
8	8	6	243	8	24	24	310
8	8	8	254	8	26	24	320
8	10	8	266	8	28	24	330
8	12	8	270	8	30	24	342
8	16	8	300	8	32	24	352
8	16	16	304	8	32	28	332
8	16	12	290	8	32	30	328
8	16	14	290	8	32	32	320
8	16	16	292	8	32	30	328
8	16	18	298	8	32	36	320
8	16	20	304	8	32	38	322
8	16	22	312	8	32	40	324

Fusible Metals for Use in Boilers, etc. —The following alloys, with their corresponding melting points, together with the temperature of steam at various pressures, may be used:

				Steam pressure by gauge.	Temp.
Tin 6	Lead 1		381°F.		
" 5	" 1		378°F.		
" 4	" 1		365°F.	120 lb.	350°F.
" 3	" 1		356°F.	105 lb.	341°F.
" 2	" 1		340°F.	90 lb.	331°F.
" 1½	" 1		334°F.	75 lb.	320°F.
" 4	" 4	Bismuth 1	320°F.	60 lb.	307°F.
" 3	" 3	" 1	310°F.	45 lb.	282°F.
" 2	" 2	" 1	292°F.	30 lb.	274°F.
" 1	" 1	" 1	254°F.	15 lb.	250°F.
" 2	" 2	" 1			292°F.
" 3	" 3	" 1			310°F.
" 4	" 4	" 1			320°F.
" 6	" 1				381°F.
" 5	" 1				378°F.
" 4	" 1				365°F.
" 3	" 1				356°F.
" 2	" 1				340°F.
" 1½	" 1				334°F.
" 1	" 1				370°F.
" 1	" 2				441°F.
" 1	" 3				482°F.
" 1	" 5				511°F.
" 1	" 10				541°F.
" 1	" 25				558°F.

So much depends, however, on the way in which an alloy is made, the purity of its original metals, and the changing conditions to which a fusible plug is subjected, that it is very doubtful whether they should ever be depended upon in critical places.

Fusible Alloys and their Melting Points.—The following alloys will melt in boiling water or at a lower temperature:

	Tin.	Lead.	Bismuth.	Cadmium.	C.	F.
Newton's	3	2	5	0	100°	212°
Rose's...	3	8	8	0	95°	203°
Erman's.	1	1	2	0	93°	199°
Wood's..	2	4	7	1	70°	158°
Mellott's.	5	3	8	0	93°	200°
Harper's.	4	4	7	1	80°	180°

Erman's alloy can be made of equal parts of plumber's half-and-half solder (equal parts tin and lead) and bismuth. Harper's alloy can be made of 8 parts of plumber's half-and-half solder, 7 parts of bismuth and 1 part of cadmium, and can be poured into a modeling composition impression. It is hard enough to withstand the hammering required, and makes a smooth, sharp die.

Fusible Alloys Containing Cadmium.—Cadmium, like bismuth, has the valuable property of lowering the melting point of many alloys, some of which are readily fusible in boiling water. Cadmium does not render the alloys so crystalline and brittle as bismuth, many of its combinations being capable of being hammered and rolled. The chief use of cadmium is in fusible alloys, which are used as solders, for castings requiring a low temperature, and in dentistry for alloys for stopping hollow teeth. Alloys of cadmium generally contain tin, lead, bismuth, and cadmium. Mercury is sometimes added to still further lower the melting point. The following table shows the composition and melting points of the more important cadmium alloys:

Alloys.	Cadmium.	Lead.	Tin.	Bismuth.	Melt'g point.
Lipowitz's..	3	8	4	15	158°F.
Fusible.....	2	11	3	16	170°F.
"	10	8	3	8	167°F.
"	1	..	2	3	203°F.
"	1	..	3	5	203°F.
"	1	..	1	2	203°F.
"	1	2	1	4	150°F.
Wood's.....	2	4	2	5	160°F.
Fusible.....	2	2	4	..	187°F.
Type metal	22½	50	36	..	.....

Copper-Cobalt

Sun-bronze.—The alloy called sun-bronze contains 10% of aluminum, 30 or 40% of copper, and 40% of cobalt. It melts at a point approaching the melting point of copper, is tenacious, ductile, and very hard.

Copper-Lead

Cock Metal.—Copper, 20 lb.; lead, 8 lb.; litharge, 1 oz.; antimony, 3 oz.

Mira Metal, Acid-proof.—This alloy is characterized by its power of resisting the action of acids, and is, therefore, especially adapted to making cocks, pipes, etc., which are to come in contact with acid fluids. It is composed of copper, zinc, lead, tin, iron, nickel, cobalt and antimony, in the following proportions: Copper, 74.755; zinc, 0.615; lead, 16.350; tin, 0.910; iron, 0.430; nickel and cobalt, each 0.240; antimony, 6.785.

Pot Metal.—This is an alloy of copper and lead, in the proportions of 8 parts of copper to 3 parts of lead. The lead is an impurity in the zinc used for making the brass. Pot metal is very brittle when warmed; it is chiefly used for making large vessels.

Lead.	Copper.	Description.
2 oz.	1 lb.	Red ductile alloy.
4 oz.	1 lb.	Red ductile alloy.
6 oz.	1 lb.	Dry pot metal or cock alloy.
7 oz.	1 lb.	Same, but shorter.
8 oz.	1 lb.	Wet pot metal.

Copper-Nickel

Argentan, White.—Zinc, 70 parts; copper, 15 parts; nickel, 6 parts.

Birmingham Platinum.—Birmingham platinum, also called platinum-lead, is composed of copper and zinc, in proportions here given:

	I.	II.	III.
Copper	46.5	43	20
Zinc	53.5	57	80

It is of a pure, nearly silver-white color, which remains unchanged by the air for some time. Unfortunately, it is so brittle that it can hardly be shaped in any way except by casting. Buttons are made of it by casting in metal molds which give sharp impressions, and the design is afterward brought out more clearly by careful pressing.

German Silver.—Albata, argentan, electrum, nickel silver, tutenag, Virginian plate, white copper. A well-known alloy, the finer varieties of which nearly equal silver in whiteness and susceptibility of receiving a high polish, while they surpass it in hardness and durability. The following formulæ are from the highest authorities:

1.—Copper, 50 parts; nickel, 20 parts; zinc, 30 parts. Very malleable, and takes a high polish.

2.—Copper, 50 parts; nickel, 26 parts; zinc, 24 parts. Closely resembles silver; an excellent sample.

3—Copper and zinc, of each 41 parts; nickel, 18 parts. Rather brittle.

4.—(M. Gersdorff.) Copper, 50 parts; nickel and zinc, of each 25 parts. Very white and malleable, and takes a high polish. Recommended as a general substitute for silver.

5.—(Gersdorff.) Copper, 60 parts; nickel and zinc, of each 20 parts. For castings, as bells, candlesticks, etc.

Nickel Bronze.—This is prepared by fusing together very highly purified nickel (99.5%) with copper, tin and zinc. A bronze is produced containing 20% of nickel, light-colored, and very hard.

Non-Magnetic Alloy for Watch Springs. —Composed of tin, copper, iron, lead, zinc, nickel and manganese. The proportions vary, but 60% of copper, 20% of nickel, and 18% of zinc, with the other ingredients, 1% or less.

Copper-Tin

Bell Metal.—1.—The various alloys used in the manufacture of bells consist essentially of copper and tin, but in some cases other metals are added in small quantities, either for cheapness or to produce a desired quality of sound. The additional metals chiefly used are zinc, lead, iron, and sometimes bismuth, silver, antimony and manganese. The following are some of the properties employed: Musical bells, 84% copper, 16% tin. Sleigh bells, 84.5% copper, 15.4% tin, 0.1% antimony. Gongs, 82% copper, 18% tin. House bells, 80% copper, 20% tin. House bells, 78% copper, 22% tin. Large bells, 76% copper, 24% tin. Swiss clock bells, 74.5% copper, 25% tin, 0.5% lead. Old bell at Rouen, 71% copper, 26% tin, 1.8% zinc, 1.2% lead. Clock bells, 72% copper, 26.56% tin, 1.44% silver. Alarm bell at Rouen, 75.1% copper, 22.3% tin, 1% zinc, 1.6% silver, Tam-tam, 79% copper, 20.3% tin, 0.52% lead, 0.18% silver. Japanese kara kane, 64% copper, 24% tin, 9% zinc, 3% iron. Japanese kara kane, 70% copper, 19% tin, 3% zinc, 8% lead. Japanese kara kane, 61% copper, 18% tin, 6% zinc, 12% lead, 3% iron. White table bells, 17% copper, 80% tin, 3% bismuth. White table bells, 87.5% tin,

12.5% antimony. Small bells, 40% copper, 60% tin.

Bronzes.—Proportions and results. In the following table the first column of figures denotes copper, the second tin.

lb.	oz.	Color.	Description.
1	0.5	Reddish yellow.	Ancient nails.
1	1.0	Reddish yellow.	Soft gun bronze.
1	1.3	Reddish yellow.	For mathematical instruments.
1	1.5	Reddish yellow.	For toothed wheels.
1	2.0	Yellow red.	Ordnance.
1	2.3	Yellow red.	Hard weapon and tool bronze.
1	2.5	Yellow red.	Hard machinery bearing bronze.
1	3.0	Bluish red.	Soft, for musical bells.
1	3.5	Bluish red.	Soft, for gongs.
1	4.0	Ash gray.	Soft, for house bells.
1	4.5	Ash gray.	Soft, for larger bells.
1	5.0	Dark gray.	Soft, for the largest bells.
1	7.0	Whitish.	Ancient mirrors.
1	8.0	Whiter.	Speculum bronze.
1	32.0	Whiter still.	Pewterers' temper.

Gun Metal.—1

No.	Copper.	Tin.	Zinc.	Color.
I	92	2	6	Pale red.
II	90	8	2	Reddish yellow.
III	84	5	11	Yellow.
IV	83	5	12	Yellow.
V	80	5	5	Pale yellowish pink.
VI	80	5	15	Yellow.
VII	75	5	20	Greenish yellow.

No. I is tough, malleable and tenacious. No. II is hard, somewhat unyielding, and easily broken. Nos. III and IV work well under the file and chisel. No. V is hard, but somewhat malleable. No. VI is hard and resisting, tough, and works fairly well with the file and chisel. No. VII is hard, and easily broken, but may be filed. The alloys are hard and brittle when the copper is less than 66% of the mixture; and when the copper is reduced to 50% the alloys are extremely hard and brittle. The addition of a little lead improves the above alloys for turning and filing.

Phosphor Bronze.—The variety of bronze known by this name is not to be considered as an alloy containing a certain amount of copper, but rather as a bronze subjected to a peculiar treatment with the use of compounds of phosphorus. Many good phosphor bronzes contain but a very small quantity of phosphorus, which exerts no essential influence upon the character of the alloy. In these cases the phosphorus acted during the preparation of the alloy. Bronze not infrequently contains a considerable quantity of cuprous oxide in solution, which is formed by direct oxidation of the copper during fusion, and this admixture is highly detrimental to the strength of the alloy. If now the melted bronze be treated with a substance capable of exerting a powerful reducing action, as, for instance, phosphorus, a complete reduction of the cuprous oxide will take place, and the bronze will acquire a surprisingly high degree of strength and power of resistance. If precisely the quantity of phosphorus necessary for the complete reduction of the oxide has been used, no phosphorus will be found in the alloy, which nevertheless must be classed as phosphor bronze. It follows from what has been said that phosphor bronze is not a special kind of alloy, but that any bronze can be made into phosphor bronze; it is, in fact, simply a deoxidized bronze. Besides its action in reducing the oxides dissolved in the alloy, the phosphorus exerts another very material influence upon the properties of the bronze. The ordinary bronzes consist of mixtures in which the copper is really the only crystallized constituent, since the tin crystallizes with great difficulty. As a consequence of this dissimilarity in the nature of the two metals, the alloy is not as solid as it would be if both were crystallized. The phosphorus causes the tin to crystallize, and the result is a more homogeneous mixture of the two metals. If enough phosphorus is added so that its presence can be detected in the finished bronze, the latter may be considered an alloy of crystallized phosphor tin with copper. If the content of phosphorus is still more increased, a part of the copper combines with the phosphorus, and the bronze then contains, besides copper and tin, compounds of crystallized copper phosphide with phosphide of tin. The strength and tenacity of the bronze are not lessened by a larger amount of phosphorus, and its hardness is considerably increased. Many phosphor bronzes are equal in this respect to the best steel, and some even surpass it in general properties. The phosphorus is added to the bronze in the form of copper phosphide or phosphide of tin, the two being sometimes used together. They must be specially prepared for this purpose, and the best methods will be here given.

Copper phosphide is prepared by heating a mixture of 4 parts of superphosphate of lime, 2 parts of granulated cop-

per and 1 part of finely pulverized coal in a crucible, at a temperature not too high. The melted copper phosphide, containing 14% of phosphorus, separates on the bottom of the crucible.

Tin phosphide is prepared as follows: Place a bar of zinc in an aqueous solution of tin chloride. The tin will be separated in the form of a spongelike mass. Collect it, and put it into a crucible upon the bottom of which sticks of phosphorus have been placed. Press the tin tightly into the crucible, and expose to a gentle heat. Continue the heating until flames of burning phosphorus are no longer observed on the crucible. The pure tin phosphide, in the form of a coarsely crystalline mass, tin-white in color, will be found on the bottom of the crucible.

To prepare the phosphor bronze the alloy to be treated is melted in the usual way, and small pieces of the copper phosphide and tin phosphide are added. Phosphor bronze, properly prepared, has nearly the same melting point as that of ordinary bronze. In cooling, however, it has the peculiarity of passing directly from the liquid into the solid state, without first becoming thickly fluid. In a melted state it retains a perfectly bright surface, while ordinary bronze in this condition is always covered with a thin film of oxide. If phosphor bronze is kept for a long time at the melting point there is not any loss of tin, but the amount of phosphorus is slightly diminished. The most valuable properties of phosphor bronze are its extraordinary tenacity and strength. It can be rolled, hammered and stretched cold, and its strength is nearly double that of the best ordinary bronze. It is principally used in cases where great strength and power of resistance to outward influences are required, as, for instance, in objects which are to be exposed to the action of sea water. Phosphor bronze containing about 4% of tin is excellently well adapted for sheet bronze. With not more than 5% of tin it can be used, forged, for firearms; 7 to 10% of tin gives the greatest hardness, and such bronze is especially suited to the manufacture of axle bearings, cylinders for steam fire engines, cogwheels, and, in general, for parts of machines where great strength and hardness are required. Phosphor bronze, if exposed to the air, soon becomes covered with a beautiful, closely adhering patina, and is, therefore, well adapted to purposes of art. The amount of phosphorus added varies from 0.25 to 2.5%, according to the purpose of the bronze. The composition of a number of kinds of phosphor bronze is given below:

(1) Copper, 90.34%; tin, 8.90%; phosphorus, 0.76%. (2) Copper, 90.86%; tin, 8.56%; phosphorus, 0.196%. (3) Copper, 94.71%; tin, 4.39%; phosphorus, 0.053%.

(I) Copper, 85.55%; tin, 9.85%; zinc, 3.77%; lead, 0.62%; iron, traces; phosphorus, 0.05%. (II) Tin, 4 to 15%; lead, 4 to 15%; phosphorus, 0.5 to 3%. (III) Tin, 4 to 15%; zinc, 8 to 20%; lead, 4 to 15%; phosphorus, 0.25 to 2%. (IV) Copper, 77.85%; tin, 11%; zinc, 7.65%. (V) Copper, 72.50%; tin, 8%; zinc, 17%. (VI) Copper, 73.50%; tin, 6%; zinc, 19%. (VII) Copper, 74.50%; tin, 11%; zinc, 11%. (VIII) Copper, 83.50%; tin, 8%; zinc, 3%.

(I) for axle bearings, (II) and (III) for harder and softer axle bearings, (IV) to (VIII) for railroad purposes, (IV) especially for valves of locomotives, (V) and (VI) for axle bearings for wagons, (VII) for connecting rods, (VIII) for piston rods in hydraulic presses.

Among other properties, phosphor bronze emits sparks under friction much less readily than gun metal or copper, and oxidizes in sea water at about one-third the rate of copper.

Speculum Metal.—1.—Chinese Mirrors. Copper, 62 parts; tin, 32 parts; lead, 6 parts.

2.—Cooper's Mirror Metal.—Copper, 57.85%; platinum, 9.49%; zinc, 3.51%; tin, 27.49%; arsenic, 1.66%. The inventor claims for this alloy that it is indifferent to the weather, and takes a beautiful polish.

3.—Reflector Metal, Duppler's.—Silver, 80 parts; zinc, 20 parts.

Bearing Metals

Alloys, Bearing.—1.

	Copper.	Tin.	Zinc.
Ordinary bearings....	84.5	13.3	2.2
Ordinary bearings....	83.6	12.6	3.8
Heavy bearings.......	84	12	4
Heavy bearings.......	77	9	14
Main bearings........	75	4	21
Locomotive axles.....	86	..	14
Locomotive axles.....	82	10	8
Moderately hard axles.	70	22	8
Hard axles..........	82	16	2
Very hard axles......	89	..	11

Copper Alloy Bearing Metals.—2.—The bearings of heavy axles, especially such as revolve rapidly, as, for example, the bearings of railroad wheels, are made, as a rule, from alloys which contain much copper (from 80 to 90%), and which may, therefore, be classed among bronze

Those containing the most copper have the valuable property of being malleable in heat, a property lacking in those which are poor in copper. A table is annexed giving the composition of some of the more important varieties of the metals of this class, and the purposes for which they are especially used. It will be found, however, that nearly every large machine foundry uses a different alloy for the same purpose. This can only be explained by the difference in the quality of the metal worked. It is evident from what has previously been said with regard to the influence of small quantities of foreign metals upon the character of an alloy, that a foundry which can obtain, for instance, only copper with a content of iron, will use a different alloy from one which works pure copper. This applies equally to all impurities present in metals; and it would mark a great advance in the technics of alloys if we were able to procure the metals for alloys, in a chemically pure state, at a low price. The result would be that the number of alloys for each certain purpose would be lessened, and the same composition would be used in all foundries.

Metals for Bearings

	Copper.	Zinc.	Tin.
Locomotive axles....	86.0	14.0	..
Locomotive axles....	82.0	8.0	10.0
Car axles...........	82.0	18.0	..
Car axles...........	84.0	16.0	..
Car axles...........	75.0	2.0	20.0
Various axles........	73.7	2.1	14.2
Various axles, medium hard........	69.55	5.88	21.77
Various axles, hard..	82.0	2.0	16.0
Various axles, very hard	88.8	11.2	..

Machine Metals for Various Purposes

Cogwheels	91.3	8.7	..	..
Punches	83.3	16.7	..	..
Steam whistles..	80.0	2.0	17.0	..
Steam whistles..	81.0	2.0	16.0	..
Cocks	88.0	2.0	10.0	..
Wheel boxes, for wagons	87.7	2.6	9.7	..
Stuffing boxes..	86.2	3.6	10.2	..
Mec'l instrum'ts	81.2	5.1	12.8	..
Files	64.4	10.0	17.6	8.6
Files	61.5	7.7	30.8	..
Weights	90.0	2.0	8.0	..
Castings, to be gilded	79.1	7.8	13.1	..
Castings, to be gilded	77.2	7.0	15.8	..

Machine Metals for Various Purposes

	Copper.	Zinc.	Tin.	Lead.
Piston rings....	84.0	8.3	2.9	4.3
Malleable shovels	50.0	16.4	33.6	..
Malleable shovels	3.0	2.0	1.0	..
Buttons, white..	57.9	36.8	5.3	..
Sheet for pressed articles	63.88	30.55	5.55	..
Small castings..	94.12	..	5.88	..
Small castings..	90.0	10.0	..	..

Brass

The term brass signifies all alloys of which copper and zinc are the essential and chief constituents; but it is generally limited in the industrial arts to those alloys which are decidedly yellow, or have the yellowish tint characteristic of ordinary brass. Alloys of zinc and copper are known in commerce by a variety of names, and, indeed, great confusion has been introduced by the multiplication of empirical names to represent one and the same substance. This is doubtless owing to the ignorance that formerly prevailed, when every mixture was jealously guarded as a great secret, and fanciful names given to hide the real composition. Moreover, some alloys have been handed down to us from very early times, and their names corrupted so as to have different appellations in different localities. Copper and zinc may be united in all proportions, forming homogeneous alloys; and the combination is usually attended with evolution of heat. Certain varieties of brass are exceedingly malleable and ductile, and these properties, combined with the variety of shades of color obtained by suitable mixing, and the moderate cost, render copper-zinc alloys most valuable for ornamental purposes. Brass possesses all the necessary advantages as a constructive material for works of art, and with the aid of transparent varnishes, termed lacquers, which have been brought to great perfection, it resists the action of the atmosphere remarkably well. The malleability of brass varies with the composition, with the temperature, and with the presence of foreign metals, which are sometimes in minute quantities. Some varieties are only malleable when rolled hot, others can be rolled at any temperature. Alloys containing up to 35% zinc can be drawn into wire, but those containing 15 to 30% of zinc are the most ductile. The alloy known as Dutch metal, which is an alloy of copper and zinc, containing more copper than ordinary brass, is an example of the great malleability of certain kinds of brass. The thickness of

the leaves of Dutch metal is said not to exceed 1-52900 of an inch. Brass is harder than copper, and therefore better adapted to resist wear and tear. It acts well under the influence of a percussive force, as in the process of stamping, provided it is suitably annealed at proper intervals, in order to counteract the effects of local hardening, due to the compression of the particles into what may be termed unnatural positions. During the ordinary process of annealing the metal becomes coated with a scale of oxide, by union with the oxygen of the air, which oxide requires to be removed at each stage. This is done by dipping the metal in aquafortis, or dilute sulphuric acid, then scouring with sand if necessary, and finally well rinsing in water. A piece of brass submitted to permanent deformation by mechanical treatment, such as rolling, is more or less hardened, and its limit of elasticity is raised. Between soft and hard brass there are many shades of difference. With the same rolled brass the author has obtained tensile strengths varying from 15 to 25 tons per square inch before and after annealing. The temperature employed for annealing is of greatest importance.

	Copper.	Tin.	Zinc.	Lead.
White metal bush for propeller ...	5	26	69	..
Cogwheels	91	..	9	..
Steam whistles...	80	17	3	..
Stuffing boxes....	86	11	3	..
Mech'l instruments	82	13	5	..
Piston rings	84	2.9	8.3	4.8
Stevenson's socket alloy	19	31	19	31
Sterro metal for pumps*	55	6	22.5	..
Valve balls†	87	12	..	..

*Also contains 16.5% iron.
†Also contains 1% antimony.

Delta Metal.—An alloy widely used for making parts of machinery, and also for artistic purposes, is the so-called Delta metal. This is a variety of brass hardened with iron; some manufacturers add small quantities of tin and lead, also, in some cases, nickel. The following analyses of Delta metal (from the factory at Düsseldorf) will show its usual composition:

	I.	II.	III.	IV.	V.
Copper..	55.94	55.80	55.82	54.22	58.65
Zinc....	41.61	40.07	41.41	42.25	38.95
Lead....	0.72	1.82	0.76	1.10	0.67
Iron....	0.87	1.28	0.86	0.99	1.62
M'ganese	0.81	0.96	1.38	1.09	....
Nickel...	*	*	0.06	0.16	0.11
Phosph's.	0.013	0.011	*	0.02	....

*Slight traces.

Tobin Bronze.—This alloy is very similar in composition and properties to Delta metal. Some analyses are given:

	I.	II.	III.	IV.
Copper ...	61.203	59.00	61.20	82.67
Zinc	27.440	38.40	37.14	3.23
Tin	0.906	2.16	0.90	12.40
Iron	0.180	0.11	0.18	0.10
Lead	0.359	0.31	0.35	2.14
Silver	....	...	...	0.07
Phosphorus	....	...	...	0.005

The alloy marked IV is called in commerce deoxidized bronze.

Some Varieties of Modern Brass

Name.	Color.	Copper.	Zinc.	Tin.	Lead.	Iron.
1. Jewelers' gilding alloy..........	Red	94	6	..	..	..
2. Jewelers' gilding alloy..........	Red	90.5	7.9	..	1.6	..
3. Pinchbeck	Reddish yellow	88.8	11.2	..	..	..
4. Orëide (French gold)..........	Reddish yellow	90	10	..	..	..
5. Talmi gold*..................	Gold	90.70	8.33	..	..	..
6. Tissier's metal, with 1% arsenic..	Red	97	2	..	..	..
7. Tournay's alloy................	Yellow	82.54	17.46	..	..	..
8. Rich sheet brass...............	Yellow	84	16	..	..	..
9. Bath metal, similor, etc.........	Yellow	80	20	..	..	..
10. Dutch alloy..................	Yellow	76	24	..	..	..
11. Bristol sheet brass.............	Bright yellow..	72.8	27	..	0.2	..
12. Brass wire....................	Bright yellow..	70	30	..	..	..
13. Prince's metal................	Yellow	75	25	..	..	..
14. Sheet and wire brass...........	Full yellow....	67	33	..	..	..
15. Mosaic gold, ordinary brass.....	Full yellow....	66.6	33.3	..	..	..
16. Bobierre's metal...............	Full yellow....	66	34	..	..	..
17. Muntz's metal.................	Full yellow....	62	38	..	..	..
18. Muntz's metal.................	Full yellow....	60	40	..	..	..

Name.	Color.	Copper.	Zinc.	Tin.	Lead.	Iron.
19. Gedge's metal	Full yellow	60	38.5	..	..	1.5
20. Common brass	Full yellow	64	36	..	..	..
21. Aich's metal	Full yellow	60	38.2	..	..	1.8
22. French brass (Potin jaune)	Gray yellow	71.9	24.9	1.2	2.0	..
23. Hamilton's metal, chrysorin	Full yellow	64.5	32.5	0.3	2.7	..
24. French brass for fine castings	Full yellow	71	24	2	3	..
25. Sterro metal		55.5	42	..	..	2.5
26. Hard solder for copper or iron		57	43	..	..	..
27. Hard solder for brass		50	50	..	..	..
28. Dipping brass		53	47	..	..	..
29. White brass		34	66	..	..	..
30. Lap alloy		12.5	87.5	..	..	..

*Also contains 0.97% gold.

Brass.—Table of Various Copper-Zinc Alloys.

Name.	Authority.	Copper.	Zinc.	Tin.	Lead.	Iron.
1. Brass, English	Lavater	70.29	29.26	0.17	0.28	..
2. Brass, Heegermuhl	Lavater	70.16	27.45	0.79	0.2	..
3. Brass, Augsburg	Lavater	70.89	27.63	0.85	..	..
4. Brass, Neustadt	Kadernatsch	71.36	28.15	..	..	..
5. Brass, Romilly	Chaudet	70.1	29.9	..	..	..
6. Brass, unknown	Karsten	71.5	28.5	..	..	..
7. Brass, unknown	Regnault	71.0	27.6	trace	1.3	..
8. Brass, unknown	Chaudet	61.59	35.33	0.25	2.86	..
9. Brass, Stolberg	Chaudet	65.8	31.8	0.25	2.15	..
10. Watch wheels	Faisst	60.66	36.88	1.35	..	0.74
11. Watch wheels	Faisst	66.06	31.46	1.43	..	0.88
12. Ship nails, bad	Percy	52.73	41.18	..	4.72	..
13. Ship nails, good	Percy	62.62	24.64	2.64	8.69	..
14. Tombac, English	Faisst	86.38	13.61	..	..	trace
15. Tombac, German	Karsten	84.0	15.5	..	..	..
16. Coin of Titus Claudius	Giraldin	81.4	18.6	..	..	..
17. Coin of Titus, 79 A.D.	Phillips	83.04	15.84	..	..	0.5
18. Coin of Hadrian, 120 A.D.	Phillips	85.67	10.83	1.14	1.73	0.74
19. Coin of Faustina, Jr., 165 A.D.	Phillips	79.15	6.67	4.97	9.18	0.23
20. Antique bracelet, Naumberg	Goebel	83.08	15.38	1.54	..	..
21. Statue of Louis XIV	D'Arcet	91.40	5.53	1.7	1.37	..
22. Statue of Napoleon	D'Arcet	75	20	3	2	..
23. Brass for gilding	D'Arcet	82	15.5	2.5	..	..
24. Brass	D'Arcet	64.5	32.5	2.5	..	..
25. Brass	D'Arcet	82	15	3	..	..
26. Brass	D'Arcet	78	20	2	..	..
27. Brass, color pale yellow	König	82.33	16.69	..	..	..
28. Brass, color deep yellow	König	84.5	15.3	..	..	..
29. Brass, color red yellow	König	90	9.6	..	..	..
30. Brass, color orange	König	98.93	0.73	..	..	..
31. Brass, color copper-red	König	99.9	..	..	..	0.08
32. Brass, color violet	König	98.22	0.5	trace	..	trace
33. Brass, color green	König	84.32	15.02	trace	..	0.3

Machine Brasses

	Copper.	Tin.	Zinc.	Lead.
Eccentric rings	90	7.7	2.3	..
Eccentric rings	66	15.5	18.5	..
Pumps	84	7	9	..
Pumps	34	50	16	..
Kingston valve	84.2	10.5	5.3	..
Cocks and glands	81	3	13	3
Paddle-wheel pins	76.8	17.4	5.8	..
Sluice cockway	81	..	19	..
Propeller blades and boxes	57	14	29	..
Hydraulic pumps	81	..	19	..
Propeller shaft liner	80	5.4	14.6	..

GOLD

Aluminum and Gold Alloy.—This alloy, called Nuremberg gold, is used for making cheap gold ware, and is excellent for this purpose, as its color is exactly that of pure gold, and does not change in the air. Articles made of Nuremberg gold need no gilding, and retain their color under the hardest usage; even the fracture of this alloy shows the pure gold color. The composition is usually 90 parts of copper, 2.5 parts of gold, and 7.5 parts of aluminum.

Chains, Alloy for.—1.—Fine gold, 11 dwts. 6 gr.; fine silver, 2 dwts. 5 gr.; fine copper, 6 dwts. 12 gr.

2.—Fine gold, 1 oz.; fine silver, 9 dwts.; fine copper, 8 dwts.

Colored Gold.—The alloys of gold with copper have a reddish tinge, those of gold with silver are whiter, and an alloy of gold, silver and copper together is distinguished by a greenish tone. Manufacturers of gold ware make use of these different colors, one piece being frequently composed of several pieces of varying color. Below are given some of these alloys, with their colors:

1.—

Gold.	Silver.	Copper.	Steel.	Cadmium.	Color.
2 to 6	1.0	...	...	...	Green
75.0	16.6	...	...	8.4	Green
74.6	11.4	9.7	...	4.3	Green
75.0	12.5	12.5	...	12.5	Green
1.0	2.0	...	...	....	Pale yellow
4.0	3.0	1.0	...	....	Deep yellow
14.7	7.0	6.0	...	....	Deep yellow
14.7	9.0	4.0	...	....	Deep yellow
3.0	1.0	1.0	...	....	Light red
10.0	1.0	4.0	...	....	Light red
1.0	...	1.0	...	....	Bright red
1.0	...	2.0	...	....	Bright red
30.0	3.0	...	2.0	....	Gray
4.0	...	...	1.0	....	Gray
29.0	11.0	...	...	....	Gray
1 to 3	...	...	1.0	....	Blue

2.—

Color	Gold.	Silver.	Copper.	Iron.	Platinum.	Cadmium.
White	..	100	..	..	...	..
White	..	...	..	..	100	..
Gray	85.7	8.6	..	5.7	...	..
Gray	83.3	..	..	16.7	...	..
Gray	72.5	27.5	..	..	...	..
Green	75	25	..	..	...	..
Green	75	16.6	..	..	...	8.4
Green	74.6	11.4	9.7	..	...	4.3
Green	75	12.5	..	..	...	12.5
Pale yell'w	91.67	8.33	..	..	...	..
Pale yell'w	91.67	..	..	8.33	...	.
Very pale.	50	50	..	..	...	..
Yellow ...	100	..	..	..	...	..
Deep yel'w	90	..	10	..	...	..
Deep yel'w	53	25	22	..	...	..
Red	75	..	25	..	...	..
Dark red.	50	..	50	..	...	..
Dark red.	25	..	75	..	...	..
Blue	75	..	..	25	...	..
Blue	66.7	..	..	33.3	...	..
Jap'ese blue gold	1 to 10	..	99 to 90	..	...	..

Imitation Gold Alloys

Gold Dutch, Mannheim gold, mosaic gold, ormolu, pinchbeck, Prince's metal, red brass similor, tombac. These names are applied to several varieties of fine gold-colored brass, differing slightly in tint, and in the proportions of copper and zinc. At the celebrated works of Hegermühl, near Potsdam, the proportions, copper 11 parts to zinc 2 parts, are employed to produce a metal which is afterward rolled into sheets for the purpose of making Dutch gold leaf. This alloy has a very rich, deep gold color. Its malleability is so remarkable that it may be beaten out into leaves not exceeding 1-52900 inch in thickness.

Leaf Brass.—1.—This alloy is also called Dutch gold, or imitation gold leaf. It is made of copper, 77.75 to 84.5 parts; zinc, 15.5 to 22.25 parts. Its color is pale or bright yellow or greenish, according to the proportions of the metals. It has an unusual degree of ductility.

2.—

	Deep gold.	Pure gold.	Pale gold.
Copper ..	84.5	78	76
Zinc	15.5	22	14

	Deep gold.	Deep gold.	Gold.
Copper ..	91	86	83
Zinc	9	14	17

IRON

Ferro-manganese is a variety of metal specially manufactured in a blast furnace from ores rich in oxide of manganese, and is very extensively used in the manufacture of mild steel. When the pig iron contains less than about 20% manganese its fracture shows large crystalline cleavage planes, and it is then termed spiegeleisen. The variety known as ferromanganese is a hard, crystalline body, but the fractured surface does not present the large cleavage planes so characteristic of spiegeleisen. It contains from 20 to 85% of manganese.

LEAD

Bullet Metal.—Lead, 98 parts; arsenic, 2 parts. For round shot, the fused metal is dropped from a high elevation in a shot tower into a basin of water; or thrown down a stack of limited height, in which a strong draught of air is produced by a blower.

Magnolia Metal.—Lead, 840 parts; antimony, 7½ parts; tin, 2½ parts; bismuth, ⅛ part; aluminum, ⅛ part; graphite, ⅛ part.

MANGANESE

Manganese Bronze.—Copper and iron unite at high temperatures in various proportions, forming alloys of great hardness, and when the iron is present in certain proportions the tenacity and elasticity of the copper are increased. The same remarks apply to brass and bronze. It should be stated, however, that the above properties are acquired at the expense of ductility and toughness.

The use of ferro-manganese in making manganese bronze is objectionable, owing to the iron introduced, but this objection can be avoided by the adoption of a rich alloy of copper and manganese, now obtainable commercially, by the use of which a very pure series of manganese bronze can readily be produced. One of the best of these, suitable for gun wheels, propellers and mining machinery, had the following composition: Copper, 53%; zinc, 42%; manganese, 3.75%; aluminum, 1.25%. The absence of iron permits the use of the large proportion of zinc without risk of rendering the metal brittle. The addition of the aluminum is necessary with the above alloy, as otherwise it is difficult to obtain sound castings.

PLATINUM

Platinum Bronze.—Several alloys of platinum, of a comparatively inexpensive nature, have been manufactured under the above name, and it has been claimed for them that they are indifferent to the action of air and water. They admit of a high polish, and retain their luster for a long time. The following are some of their compositions and uses: For table utensils, nickel, 90%; platinum, 0.9%; tin, 9%. For bells, nickel, 81.5%; platinum, 0.8%; tin, 16%; silver, 1.7%. For articles of luxury, nickel, 86.5%; platinum, 0.5%; tin, 13%. For tubes for telescopes, etc., nickel, 71%; platinum, 14.5%; tin, 14.5%. For ornaments, nickel, 31.6%; platinum, 3.2%; brass, 65.2%.

SILVER

Silver and Aluminum.—1.—Alloys of these metals were made some years ago, and it was thought that valuable metals of a white color, and unaffected by the atmosphere, would be obtained, which would make them superior to ordinary silver-copper alloys; but these great expectations have not as yet been realized. Aluminum hardens silver, and the alloys admit of a high polish.

2.—Tiers-Argent.—This alloy is chiefly prepared in Paris, and used for the manufacture of various utensils. As indicated by its name (one-third silver), it consists of 33.33 parts of silver and 66.66 parts of aluminum. Its advantages over silver consist in its lower price and greater hardness; it can also be stamped and engraved more easily than the alloys of copper and silver.

Silver, Copper, Nickel and Zinc.—These alloys, from the metals contained in them, may be characterized as argentan or German silver with a percentage of silver. They have been used for making small coins, as in the older coins of Switzerland. Being quite hard, they have the advantage of wearing well, but soon lose their beautiful white color and take on a disagreeable shade of yellow, like poor brass. The silver contained in them can only be regained by a laborious process, which is a great drawback to their use in coinage.

1.—The composition of the Swiss fractional coins is as follows:

	20 centimes.	10 centimes	5 centimes.
Silver	15	10	5
Copper	50	55	60
Nickel	25	25	25
Zinc	10	10	10

2.—Argent-Ruolz.—The articles which are manufactured by the Paris firm of Ruolz, under the name of Ruolz silver, or Argent Francais, resemble pure silver perfectly in appearance, but differ from the latter in greater hardness and a much lower price. According to the quality of the object, various alloys are employed in the factories of Ruolz silver. We give below the composition of some of the alloys as produced in the French factories:

	I.	II.	III.
Silver	33	40	20
Copper	37-42	30-40	45-55
Nickel	25-30	20-30	25-35

3.—Sterling silver.—Fine silver, 5 oz. 11 dwt.; fine copper, 9 dwt.

4.—Equal to sterling-fine silver, 1 oz.; fine copper, 1 dwt. 12 gr.

5.—Niello.—This consists of silver, 9 parts; copper, 1 part; lead, 1 part; bismuth, 1 part; which are melted together, and saturated with sulphur. This mixture produces the gorgeous blue which has often been erroneously spoken of as steel blue.

Silver and Nickel.—Berthier described an alloy of these metals containing 13.5% nickel which was white, and capable of a high polish; it rolled well, and was very tough. There appears to be very little known concerning alloys of these two metals alone.

Silver and Tin.—1.—A very small quantity of tin renders silver brittle. Alloys of tin and silver, according to Guettier, are harsh, very hard, and brittle. An alloy of 80% tin is nearly as hard as bronze. An alloy of 52% tin is somewhat malleable. These alloys are very easily oxidized. They have a specific gravity less than the mean of the constituents. Tin may be removed from silver by fusion with bichloride of mercury (corrosive sublimate), leaving the silver pure. Dentists use an alloy of 60 parts silver and 40 parts tin, in admixture with mercury, for filling teeth.

2.—Dental Alloys.—(a) Tin, 91.63 parts; silver, 3.82 parts; copper, 4.4 parts. (b) Tin, 36.78 parts; silver, 48.32 parts; gold, 14.72 parts.

Silver and Zinc.—Silver and zinc have great affinity for each other, and alloys of these two metals are, therefore, easily made. The required quantity of zinc, wrapped in a paper, is thrown into the melted and strongly heated silver, the mass is thoroughly stirred with an iron rod, and at once poured out into molds. Alloys of silver and zinc can be obtained which are both ductile and flexible. An alloy consisting of 2 parts of zinc and 1 part of silver closely resembles silver in color, and is quite ductile. With a larger proportion of zinc the alloys become brittle. In preparing the alloy, a somewhat larger quantity of zinc must be taken than the finished alloy is intended to contain, as a small amount always volatilizes. Berthier prepared an alloy containing 80% of silver, which he states was rolled into very thin leaf; it was rigid, elastic, very tenacious, and tough.

Silver Substitutes.—1.—A writer gives the constituents of a hard alloy which has been found very useful for the spacing levers of typewriters. The metal now generally used for this purpose by the various typewriter companies is "aluminum silver," or "silver metal." The proportions are given as follows: Copper, 57%; nickel, 20%; zinc, 20%; aluminum, 3%. This alloy, when used on typewriting machines, is nickel-plated, for the sake of the first appearance; but so far as corrosion is concerned, nickeling is unnecessary. In regard to its other qualities, they are of a character that recommends the alloy for many purposes. It is stiff and strong, and cannot be bent to any extent without breaking, especially if the percentage of aluminum is increased to 3.5%; it casts free from pinholes and blowholes. The liquid metal completely fills the mold, giving sharp, clean castings, true to pattern; its cost is not greater than brass; its color is silver white, and its hardness makes it susceptible of a high polish.

2.—Iron, 65 parts; tungsten, 4 parts; melted together and granulated. Also nickel, 23 parts; aluminum, 5 parts; copper, 5 parts; in a separate crucible, to which is added a piece of sodium, in order to prevent oxidation. The two granulated alloys are then melted together. Both alloys resist the action of sulphuretted hydrogen.

TIN

Bearing Metals

Anti-friction Metal.—1.—Tin, 16 to 20 parts; antimony, 2 parts; lead, 1 part; fused together and then blended with copper, 80 parts. Used where there is much friction or high velocity.

2.—Zinc, 6 parts; tin, 1 part; copper, 20 parts. Used when the metal is exposed to violent shocks.

3.—Lead, 1 part; tin, 2 parts; zinc, 4 parts; copper, 68 parts. Used when the metal is exposed to heat.

4.—(Babbitt's.) Tin, 48 to 50 parts; antimony, 5 parts; copper, 1 part.

5.—(Fenton's.) Tin, with some zinc and a little copper.

6.—(Ordinary.) Tin, or hard pewter, with or without a small portion of antimony or copper. Without the copper it is apt to spread out under the weight of heavy machinery. Used for the bearings of locomotive engines, etc.

Babbitt Metal.—"Genuine" babbitt is composed of a small quantity of copper added to tin and antimony. No lead is used, for the adjective "genuine" is applied especially to distinguish it from the cheaper grades containing lead. There is considerable temptation to adulterate it with lead, owing to the difference in value of lead and tin; 1 lb. of lead added to 100 lb. of "genuine" makes a gain of about

3.— Table of White Alloys.

Description.	Silver. dwts.	Nickel. dwts.	Brass. lb.	Zinc. dwts.	Tin. lb.	Lead. lb.	Copper. lb.	Antimony. lb.	Bismuth. lb.
Nickel, or German silver	...	3.0	....	16.0	....	...	1.0	...	...
White copper of China	...	15.0	....	13.0	....	...	1.0	...	...
Queen's metal	...	....	....	....	9.0	2.0	...	1.0	2.0
				lb.					
Britannia metal	...	....	1.0	....	49.0	...	1.0	3.5	...
White button metal....	...	....	16.0	2.0	1.0	...	...	...	...
Solder for bell metal..	...	....	2.0	....	1.5	...	1.0	...	...
Solder for brass........	...	....	1.0	....	0.6	...	0.15	...	...
Solder for tin..........	...	....	....	....	1.0	0.5	...	...	...
Solder for silver........	1.0	....	0.5	....	....	...	...	...	...
Solder for silver........	1.0	....	0.3	....	....	...	...	...	...
Solder for silver........	4.0	....	....	....	....	...	1.0	...	...
Solder for Mokume....	1.0	....	0.15	....	....	...	...	...	...
French coin	835.0	....	....	....	....	...	165.0	...	...
M. Piligot's coin alloy..	950.0	....	....	50.0	....	...	...	...	...
M. Piligot's coin alloy..	900.0	....	....	100.0	....	...	...	...	...
M. Piligot's coin alloy..	800.0	....	....	200.0	....	...	...	...	...
M. Piligot's coin alloy..	900.0	....	....	50.0	....	...	50.0	...	...
M. Piligot's coin alloy..	800.0	....	....	100.0	....	...	100.0	...	...
M. Piligot's coin alloy..	835.0	....	....	72.0	....	...	93.0	...	...
Gin shi bu ichi........	100.0	....	....	....	....	...	30 to 50	...	...

18 cents. The character of the alloy would not be greatly altered, but when the purchaser pays for the best he certainly has a right to expect it. Fortunately, it is easy to detect such adulteration. Take a piece and use it for a pencil; if it makes a mark, then it contains lead, as a small amount of lead added to tin causes the latter to mark paper.

White Metal.—The so-called white metals are employed almost exclusively for bearings. In the technology of mechanics an accurate distinction is made between the different kinds of metals for bearings; and they may be classed in two groups, red-brass and white metal. The red-brass bearings are characterized by great hardness and power of resistance, and are principally used for bearings of heavily loaded and rapidly revolving axles. For the axles of large and heavy fly-wheels, revolving at great speed, bearings of red brass are preferable to white metal, though more expensive. In recent years, many machinists have found it advantageous to substitute for the soft alloys

White Metals for Bearings

	Tin.	Antimony.	Zinc.	Iron.	Lead.	Copper.
German, light loads........	85.00	10.00	.....	.....	.....	5.00
German, light loads........	82.00	11.00	.....	.....	.....	7.00
German, light loads........	80.00	12.00	.....	.....	.....	8.00
German, light loads........	76.00	17.00	.....	.....	.....	7.00
German, light loads........	3.00	1.00	5.00	.....	3.00	1.00
German, heavy loads.......	90.00	8.00	.....	.....	.....	2.00
German, heavy loads.......	86.81	7.62	.....	.....	.....	5.57
English, heavy loads.......	17.47	.....	76.14	.....	.....	5.62
English, medium loads......	76.70	15.50	.....	.....	.....	7.80
English medium loads......	72.00	26.00	.....	.....	.....	2.00
For mills	15.00	.....	40.00	.....	42.00	3.00
For mills	.....	1.00	5.00	.....	5.00	....
For mills	.....	1.00	10.00	.....	2.00	....
Heavy axles	72.70	18.20	.....	.....	.....	9.10
Heavy axles	38.00	6.00	47.00	.....	4.00	1.00
Rapidly revolving axles....	17.00	77.00	.....	.....	.....	6.00
Very hard metal...........	55.00	.....	.....	70.00	.....	2.50
Very hard metal...........	12.00	82.00	2.00	.....	.....	4.00
Cheap metal	2.00	2.00	88.00	.....	.....	8.00
Cheap metal	1.50	1.50	90.00	.....	.....	7.00

White Alloys for Bearings

	Tin.	Copper.	Antimony.	Lead.	Zinc.	Iron.
Kingston's metal with 6% of mercury added	88.0	6.0	....	....	....	....
Fenton's metal for axle boxes of locomotives and wagons	14.5	5.5	....	....	80.0	....
Stephenson's alloy	31.0	19.0	....	....	19.0	31.0
For propeller boxes	14.0	57.0	....	....	29.0	....
Dew Pance's metal for locomotives	33.3	22.2	44.4	....	....	....
Hoyle's alloy for pivot bearings	46.0	....	12.0	42.0	....	....
Jacoby's alloy	85.0	5.0	10.0	....	....	....
For propeller bush	26.0	5.0	....	....	69.0	....
Very hard bearing	12.0	4.0	82.0	....	2.0	....
Anti-friction metal	14.0	6.0	....	....	80.0	....
For general bearings	81.0	5.0	....	14.0	....	....
For general bearings	81.0	5.0	14.0	....	....	....
For general bearings	....	10.0	10.0	80.0	....	....
For general bearings	....	12.0	....	88.0	....	....
Bearings for light work	85.0	5.0	10.0	....	....	....
Bearings for light work	73.0	9.0	18.0	....	....	....
Bearings for light work	76.0	7.0	17.0	....	....	....
Bearings for heavy work	90.0	2.0	8.0	....	....	....
Bearings for heavy work	87.0	6.0	7.0	....	....	....
Bearings for common work	2.0	8.0	2.0	....	88.0	....
Soft alloy for pillow blocks	....	....	15.0	85.0	....	....
Vaucher's alloy for lining journals	18.0	....	2.5	4.5	75.0	....

generally in use for bearings a metal almost as hard as the axle itself. Phosphor bronze is frequently employed for this purpose, as it can easily be made as hard as wrought or cast steel. In this case the metal is used in a thin layer, and serves only, as it were, to fill out the small interstices caused by wear on the axle and bearing, the latter being usually made of some rather easily fusible alloy of lead and tin. Such bearings are very durable, but expensive, and can only be used for large machines. For small machines, running gently and uniformly, white-metal bearings are preferred, and do excellent work, if the axle is not too heavily loaded. For axles which have a high rate of revolution, bearings made of quite hard metals are chosen, and with proper card—which, indeed, must be given to bearings of any material—they will last for a long time without needing repair.

Britannia Metals

Britannia metal is an alloy consisting principally of tin and antimony. Many varieties contain only these two metals, and may be considered simply as tin hardened with antimony, while others contain, in addition, certain quantities of copper, sometimes lead, and occasionally, though rarely, on account of its cost, bismuth. Britannia metal is always of a silvery-white color, with a bluish tinge, and its hardness makes it capable of taking a high polish, which is not lost through exposure to the air. Tin, 90%, and antimony 10%, give a composition which is the best for many purposes, especially for casting, as it fills out the molds well, and is readily fusible. In some cases, where articles made from it are to be subjected to constant wear, a harder alloy is required. In the proportions given above the metal is indeed much harder than tin, but would still soon give way under usage. A table is appended giving the composition of some of the varieties of Britannia metal and their special names:

	Tin.	Antimony.	Copper.	Zinc.	Lead.
English	81.90	16.25	1.84	....	....
English	90.62	7.81	1.46	....	....
English	90.1	6.3	3.1	0.5	....
English	85.4	9.66	0.81	3.06	....
Pewter	81,2	5.7	1.60	....	11.5
Pewter	89.3	7.6	1.8	....	1.8
Tutania	91.4	.....	0.7	0.3	7.6
Queen's metal	88.5	7.1	3.5	0.9	....
German	72	24	4	....	....
German	84	9	2	5	....
German (for casting)	20	64	10	6	....
Malleable (for casting)	48	.....	3	48	1

Britannia metal is prepared by melting the copper alone first, then adding a part of the tin and the whole of the antimony. The heat can then be quickly moderated, as the melting point of the new alloy is much lower than that of copper.

Finally, the rest of the tin is added, and the mixture stirred constantly for some time to make it thoroughly homogeneous.

Tin-Lead

1.—In former times, before porcelain came into general use, alloys of tin and lead were very extensively used for the manufacture of the so-called tin-ware, which probably never consisted of pure tin, but always of a mixture of tin and lead. Tin is one of those metals which is not at all susceptible to the action of acids, while lead, on the other hand, is very easily attacked by them. In such alloys, consequently, used for cooking utensils, the amount of lead must be limited, and should properly not exceed 10 or 15%; but cases have been known in which the so-called tin contained a third part, by weight, of lead. Alloys containing from 10 to 15% of lead have a beautiful white color, are considerably harder than pure tin, and much cheaper. Many alloys of tin and lead are very lustrous, and are used for stage jewelry and mirrors for reflecting the light of lamps, etc. An especially brilliant alloy is called "Fahlun brilliants." It is used for stage jewelry, and consists of 29 parts of tin and 19 parts of lead. It is poured into molds faceted in the same way as diamonds, and when seen by artificial light the effect is that of diamonds. Other alloys of tin and lead are employed in the manufacture of toys. These must fill the molds well, and must also be cheap, and therefore as much as 50% of lead is used. Toys can also be made from type metal, which is even cheaper than the alloys of tin and lead, but has the disadvantage of readily breaking if the articles are sharply bent. The alloys of tin and lead give very good castings, if sharp iron or brass molds are used.

2.—Tin, 82 parts; lead, 18 parts, antimony, 5 parts; zinc, 1 part; copper, 4 parts.

Pewter.—1.—Prep. (Aiken.) Tin, 100 parts; antimony, 8 parts; copper, 4 parts; bismuth, 1 part: fuse together. Very fine.

2.—Plate Pewter.—Tin, 100 parts; antimony, 8 parts; bismuth and copper, of each 2 parts. Very fine. Used to make plates, etc.

3.—Trifle.—Tin, 83 parts; antimony, 17 parts. Some lead is generally added.

4.—Ley.—Tin, 4 parts; lead, 1 part. Used for beer pots, etc.

5.—Best Pewter.—Tin, 5 lb.; lead, 1 lb.

6.—Common Pewter.—Pure tin, 82 parts; lead, 18 parts.

7.—Plate Pewter.—Tin, 90 parts; antimony, 7 parts; bismuth, 2 parts; copper, 2 parts.

Stereotype Metal

Tin, 1 part; antimony, 1 part; lead, 4 parts. In using stereotype metal, brush the type with plumbago or a small quantity of oil, then place in a frame, and take a cast with plaster of paris. The cast is dried in a very hot oven, placed face downward upon a flat plate of iron; this plate is laid in a tray or pan of iron having a lid securely fastened, and furnished with a hole at each corner. Dip the tray in the fluid metal, which will flow in at the four corners. When the tray is removed, dip the bottom only in water; and as the metal contracts in cooling, pour in melted metal at the corners, so as to keep up the fluid pressure, and obtain a good solid cast. When cool, open the tray, remove the cake of plaster and metal, and beat the edges with a mallet to remove superfluous metal. Plane the edges square, turn the back flat, in a lathe, to the required thickness, and remove any defects. If any letters are damaged, cut them out and solder in separate types instead. Finally, fix upon hardwood to the required height.

Type Metals

An alloy which is to serve for type metal must allow of being readily cast, fill out the molds sharply, and be as hard as possible. It is difficult to satisfy all these requirements entirely, but an alloy of antimony and lead answers the purpose best. At the present day there are a great many formulæ for type metal in which other metals besides lead and antimony are used, either to make the alloy more readily fusible, as in the case of

1.—	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.
Lead	3	5	10	10	70	60	55	55	100	6
Antimony	1	1	1	2	18	20	25	30	30	..
Copper	..	..	..	..	2	..	..	..	8	4
Bismuth	..	..	..	1	..	..	..	..	2	..
Zinc	..	..	..	..	..	..	..	..	..	90
Tin	..	..	..	..	10	20	20	15	20	..
Nickel	..	..	..	..	..	..	..	..	8	..

2.—Type Metal, Alloys used for.

	Lead.	Antimony.	Tin.	Bismuth.	Copper.	Zinc.	Arsenic.
Printing types	4.0	1.0	....	...	...	....	...
Printing types	7.5	2.5	....	...	0.5	....	...
Printing types	9.0	1.0	....	...	...	....	0.5
Printing types	64.0	8.0	12.0	...	...	16.0	...
Small types and stereotypes	9.0	2.0	....	2.0	...	....	...
Small types and stereotypes	16.0	4.0	5.0	...	...	....	...
Small types and stereotypes	3.0	1.0	....	...	...	....	...
Small types and stereotypes	5.0	1.0	....	...	...	....	...
Small types and stereotypes	10.0	2.0	....	1.0	...	....	...
Plates for engraving music, etc.	....	5.0	5.0	...	...	....	...
Plates for engraving music, etc.	....	2.5	7.5	...	...	....	...
Plates for engraving music, etc.	64.0	8.0	12.0	...	...	16.0	...
Plates for engraving music, etc.	60.0	2.5	37.5	...	...	....	...

additions of bismuth, or to give it greater power of resistance, the latter being of especial importance in newspaper types, which are subjected to constant use. Copper and iron have been recommended for this purpose, but the fusibility of the alloys is greatly impaired by these, and the manufacture of the types is consequently more difficult than with an alloy of lead and antimony alone. In the preceding table some alloys suitable for casting type are given:

TUNGSTEN BRONZES

In the arts, tungsten bronzes of different colors are used, namely, golden yellow, reddish yellow, purple red, and blue. The first two crystallize in forms resembling cubes, while the third is obtained partially in cubes and partially in amorphous pieces, and the last named forms prismatic crystals. Other circumstances being equal, the yellow bronze is obtained from mixtures poor in acid, the other two from those containing more acid. But the color is dependent not merely on the composition of the soda tungstate salt, but also on the amount of tin, and on the duration of the fusion; so that when much tin is used, and the fusion is prolonged, a yellow bronze is obtained from a very acid mixture, and, on the contrary, a salt that is but slightly acid, when fused only a short time and with very little tin, may yield a red or even a blue bronze.

A mixture in the proportion of 2 molecules of soda tungstate and 1 molecule of anhydrous tungstic acid, with tinfoil slowly added, and kept melted for 1 or 2 hours, will yield cubes 1-5 in. long when about 4 oz. are melted, and they will produce a yellow or reddish-yellow bronze, the powder of which seems light brown, and when stirred up with water it imparts to the liquid the property of appearing of a fine blue color by transmitted light.

The red bronze obtained from 10 parts of soda carbonate, 70 parts of soda tungstate, and 20 parts of tinfoil, yields, on pulverization, a powder that, stirred up in water, transmits green light.

According to J. Philipp, a blue bronze is always obtained, if the fused mixture contains more than 3 molecules of tungstic acid to 1 molecule of soda; if the fused product is boiled alternately with muriatic acid and with carbonate of soda, the result will be a considerable quantity of fine blue prismatic crystals with which there are intermixed, in most cases, single red and yellow cubes. Moreover, all the tungsten bronzes obtained by fusion with tin can also be prepared by electrolysis of fused acid tungstates, but the yield is so small that it is unprofitable.

ZINC

Zinc Bronzes (Fontainemoreau).

Zn.	Cu.	Fe.	Pb.
90	8	1	1
91	8	0	1
92	8	0	0
92	7	1	0

The above may be considered the maximum of zinc and minimum of copper that will cast free of crystalline fracture. By lessening the zinc from 1 to 4%, and increasing the copper 1-8 to 1-6, a better texture may be looked for.

Zinc-Nickel.—Zinc, 9 parts; nickel, 1 part. Used for painting.

AMALGAMS

Mercury is well known to be the only metal which is liquid at ordinary temperatures. The best mercury is crystalline in character, and of a silver-white color, freezing at —40° F. and boiling at 662°. When compounded with other metals it forms alloys whose properties differ greatly according to the nature of the metals used. In most cases the

amalgams are at first liquid, and afterward become crystalline, any mercury in excess being separated. The amalgams offer an excellent opportunity for studying the behavior of the metals toward each other, the low temperature at which these compounds are formed making the examination easier. If a metal is dissolved in mercury with an excess of the latter, a crystalline compound will soon separate from the originally liquid mass. This is the amalgam, whose proportions can be expressed according to fixed atomic weights, and easily obtained by removing the excess of mercury by pressure. Many amalgams are at first so soft that they can be kneaded in the hand like wax, but become hard and crystalline in time. These are especially adapted for filling teeth, and much used for that purpose. Before the action of the galvanic current upon metallic solutions was known, by means of which certain metals can be separated in a pure state from solutions, and deposited upon a given surface, the amalgams were of great importance in gilding and silvering. The article was coated with the amalgam, and the mercury volatilized by heat, the gold or silver remaining upon the surface as a coherent coat. The process was called fire gilding. The chemical affinity of other metals for mercury varies greatly; many combine with it very easily, others with such difficulty that an amalgam can only be obtained in a roundabout manner. Amalgams are of great interest theoretically, and important to a general knowledge of alloys, but only a limited number are actually employed in the industries.

Bismuth Amalgam

Mercury and bismuth can be very easily combined by melting the latter and introducing the mercury. The resulting amalgam is very thinly fluid, and can be used for filling out very delicate molds. An addition of bismuth also makes other amalgams more thinly fluid. Such combinations are cheaper than pure bismuth amalgam, and frequently used.

Bismuth amalgams can be used for nearly all purposes for which cadmium amalgams are employed. On account of their fine luster, which equals that of silver, they are applied to special purposes, such as curved mirrors, and the preparation of anatomical specimens.

Bismuth Amalgams.—The amalgam formed of 1 part of bismuth and 4 parts of quicksilver will cause the strong adherence of glass. For the purpose of economizing the bismuth, of which the price is high, the preceding amalgam is replaced by another composed of 2 parts of quicksilver, 1 part of bismuth, 1 part of lead and 1 part of tin. The bismuth, broken into small fragments, is added to the tin and lead, previously melted in the crucible, and when the mixture of the three metals becomes fluid the quicksilver is poured in, while stirring with an iron rod. The impurities floating on the surface are removed, and when the temperature is sufficiently lowered this amalgam is slowly poured into the vessels to be tinned, which have been previously well cleaned and slightly heated. M. Ditte recommends for the same employment, as a very strong adherent to the glass, an amalgam obtained by dissolving, hot, 2 parts of bismuth and 1 part of lead in a solution of 1 part of tin in 10 parts of quicksilver. By causing a quantity of this amalgam to move around the inside of a receiver, clean, dry, and slightly heated, the surface will be covered with a thin, brilliant layer, which hardens quite rapidly.

Cadmium Amalgam

Cadmium Amalgams.—Amalgams of cadmium, formed of equal weights of cadmium and quicksilver, have much power of cohesion, and are quite malleable; the case is the same with an amalgam formed of 1 part of cadmium and 2 parts of quicksilver. They are used as dental cements, for plugging teeth; for the same purpose an amalgam of 2 parts of quicksilver, 1 part of cadmium and 2 parts of tin may be used.

Evans's Metallic Cement.—This alloy is prepared by dissolving cadmium amalgam (25.99 parts of cadmium and 74.01 parts of mercury) in an excess of mercury, slightly pressing the solution in a leather bag and thoroughly kneading. If the amalgam is first heated to about 97° F., and then kneaded, it becomes as plastic as wax, and can be shaped into any desired form. On cooling, it becomes quite hard, but does not equal in this respect the pure cadmium amalgam.

Copper Amalgam

The peculiar properties of copper amalgam give it quite an important place in several branches of industry. It crystallizes very easily, and becomes so hard that it can be polished like gold. It can also be hammered or rolled, and stamped, and retains its luster for a long time in the air, unless the air contains hydrogen sulphide, in which case it quickly tarnishes and turns black. If placed in boiling water it becomes soft, and so pliable that it can be shaped into the most

delicate forms, hardening again in a few hours to a very fine-grained, quite malleable mass. It was formerly recommended for filling teeth, but is no longer used for that purpose, as there are other amalgams equally suitable, and free from copper, which has a poisonous effect. An important use of copper amalgam is in cementing metals; it is only necessary to apply it to the metals. which must be bright, and previously heated to from 176 to 194° F., and press them together; they will be joined firmly.

There are many methods of preparing copper amalgam, but the simplest and easiest is as follows: Place strips of zinc in a solution of copper sulphate, and shake vigorously. The copper thus obtained, in the form of a delicate powder, is washed and treated, while still moist, in a rubbing-dish, with a solution of mercurous nitrate. Hot water is then poured over the copper, the dish kept warm, and the mercury added. The contents of the dish are kneaded with a pestle until the powdery copper has combined with the mercury to a plastic mass, which will become the more homogeneous the longer the kneading is continued. The best proportions are 3 parts of copper to 7 parts of mercury.

When the amalgam has reached the proper consistency the water is poured off, and the soft mass molded into the form in which it is to remain. For the purpose of cementing, it has been found best to roll it into small cylinders, about ⅛ in. in diameter and ¾ to 1½ in. long. To take impressions with this amalgam, of casts made from wood carvings, the amalgam is rolled out, while warm, into a thin sheet, and pressed firmly upon the cast, also warmed. After the amalgam has hardened, the thin sheet can be made stronger by pouring over it melted type metal.

Gold Amalgam

Gold belongs among these metals which combine easily with mercury, and a gold amalgam can be prepared by direct union of the two metals. If gold is used which has been obtained by the chemical process of reducing gold salts, it must be remembered that this, being in a finely divided state, will not dissolve easily in the mercury, for the reason that the fine powder will remain floating upon the surface. Gold, however, which has been reduced in the form of somewhat larger crystals, will dissolve in a comparatively short time. These small gold crystals can easily be obtained by dissolving gold chloride in amyl alcohol and heating the solution to the boiling point, whereby the gold will be separated in the form of small, lustrous crystals.

Iron Amalgam

Iron is one of the metals which does not combine easily with mercury, and iron amalgam, as such, is not used for plating purposes.

Lead Amalgams

These meet with an interesting employment for the autogenous soldering of lead. After the surfaces to be soldered have been well cleaned a layer of lead amalgam is applied. It is afterward sufficient to pass along the line of junction a soldering iron heated to redness, in order that the heat should cause the volatilization of the quicksilver, and that the lead, liberated in a state of fine division, should be melted and cause the adherence of the two surfaces. The only precaution necessary is to avoid breathing the mercurial vapor, which is quite poisonous.

Silver Amalgam

The properties of silver amalgam are similar in most respects to those of gold amalgam, but it has a still stronger tendency to crystallize. Pure silver must be used in its preparation, as a content of copper would have the same detrimental effect upon the character of the amalgam as in the case of gold amalgam. The easiest method of making silver amalgam is by the use of silver in powdered form, obtained by reducing silver solutions. If a solution of nitrate of silver is put into a bottle with 10 or 15 parts of water, and a few small pieces of sheet zinc, and the mixture shaken vigorously for a few minutes, the silver will separate in the form of a very fine blackish-gray powder, which only needs washing and drying to be ready for the preparation of amalgam. This powder can be directly dissolved in the mercury, but it takes some time. A quicker method is to heat the mercury nearly to the boiling point in a crucible, and throw in the powdered silver, stirring vigorously with an iron rod. Silver amalgam can also be prepared without heat. In this method a concentrated solution of nitrate of silver (1 part of the nitrate in 3 parts of distilled water) is mixed with 4 times the quantity of mercury, and the liquids combined by shaking. The silver will be reduced from the nitrate by the mercury, and dissolve in the excess of it. If the amalgam is to be used for fire silvering, the small quantity of nitrate of mercury

adhering to it is of no consequence, and it can be used at once.

Tin Amalgam

This amalgam was formerly of importance for making mirrors, but at the present day mirrors coated with a thin layer of silver are more beautiful and cheaper than those prepared with amalgam. Tin has a great affinity for mercury, which makes the preparation of the amalgam easy. It is only necessary to rub the two together, the tin being best used in the form of foil or shavings. The amalgam will harden in a shorter or longer time, according to the quantity of mercury used.

Zinc Amalgam

Zinc amalgamates readily with mercury, it being only necessary to heat the latter to the boiling point and add the zinc in small pieces. Zinc amalgam is not employed directly, but is largely used in the zinc anodes of galvanic batteries. For this purpose it is prepared upon the zinc plate itself, by heating the latter to about 482 to 500° F., and dipping it at once into mercury, after first coating it quickly and uniformly with a solution of chloride of zinc and ammonia, applied with a brush. Amalgamation takes place immediately, and the plates thus treated give currents of greater strength and constancy than ordinary zinc plates.

CHAPTER II.

CEMENTS, GLUES, PASTES, ETC.

GENERAL SCHEME OF CLASSIFICATION

CEMENTS PROPER
- ACID-PROOF
- AQUARIUM
- CASEIN
- CELLULOID
- GLASS, ETC.
- LEATHER
- MECHANICS'
- METALS
- METALS TO GLASS, ETC.
- METALS TO LEATHER, ETC.

CEMENTS PROPER—Continued
- RUBBER
- WOOD TO WOOD
- MINOR USES

OTHER ADHESIVES
- GLUE
- MUCILAGE
- PASTES
- PUTTY
- SPECIAL ADHESIVES

The importance of cements, both in the workshop and in the household, is universally acknowledged, but the frequency of failures in the use of them shows that no matter how good the receipt, or how carefully compounded, if the cement is carelessly applied or allowed an insufficient time for setting, bad results are sure to follow. By observing the following simple rules much time and money can be saved:

1.—See that the surfaces are clean. Dirt and grease are sure to breed trouble. Wash the article with lye (caustic potash), or if from the nature of the substance lye cannot be used, with carbon bisulphide. The hands are very liable to be greasy, and the edges to be joined should not be touched by them. If the substances to be united have been joined before, all traces of the former cement must be removed.

2.—Bring the cement into intimate contact with the surfaces to be united. This is best done by heating the pieces to be joined in those cases where the cement is melted by heat, as in using rosin, shellac, marine glue, etc. This heating is of great importance and is usually neglected, to the detriment of the strength of the joint. This fact is understood by cement peddlers, and some of the really marvelous feats performed by them are entirely owing to this cause. Where solutions are used the cement must be well rubbed into the surfaces, either with a soft brush (as in the case of porcelain or glass) or by rubbing the two surfaces together (as in making a glue joint between two pieces of wood).

3.—As little cement as possible should be allowed to remain between the united surfaces. To secure this the cement should be as liquid as possible (thoroughly melted if used with heat), and the surfaces should be pressed closely into contact (by screws, weights, wedges or cords) until the cement has hardened. These mechanical aids also help to displace the thin film of air which sticks closely to the substance. The ordinary carpenter's hand screw is recommended for use with cements. It is in use by all cabinet makers and carpenters for gluing. A string tightly bound about the object answers the same purpose and is good if tight. All excess should be removed from the edges while the cement is still liquid. Plenty of time should be allowed for the cement to dry or harden, and this is particularly the case in oil cements, such as copal varnish, boiled oil, white lead, etc. When 2 surfaces, each ½ in. across, are joined by means of a layer of white lead placed between them, 6 months may elapse before the cement in the middle of the joint has become hard. In such cases a few days or weeks are of no account; at the end of a month the joint will be weak and easily separated, while at the end of 2 or 3 years it may be so firm that the material will part anywhere else than at the joint.

Hence when the article is to be used immediately the only safe cements are those which are liquified by heat and which become hard when cold. A joint made with marine glue is firm an hour after it has been made. Next to cements that are liquified by heat are those which consist of substances dissolved in water or alcohol. A glue joint sets firmly in 24 hours; a joint made with shellac varnish becomes dry in 2 or 3 days. Oil cements, which do not dry by evaporation, but harden by oxidation (boiled oil, white lead, red lead, etc.), are the slowest of all.

4.—Coloring matters may be introduced into cements with good effect. But care should be used not to mix anything with the cement which will set up any chemical action and so weaken the joint.

5.—Select the right recipe from the following very full list of cements, which contains all which are of value and many which are published for the first time. A good rubber cement, shellac varnish and a good gutta percha cement as the following should be on every amateur's work table.

A Strong and Handy Cement.—One of the strongest cements, and very readily made, is obtained when equal quantities of gutta percha and shellac are melted together and well stirred. This is best done in an iron capsule placed on a sand bath and heated either over a gas furnace or on the top of a stove. It is a combination possessing both hardness and toughness—qualities that make it particularly desirable in mending crockery. When this cement is used, the articles to be mended should be warmed to about the melting point of the mixture, and then retained in proper position until cool, when they are ready for use.

ACID-PROOF CEMENTS

1.—Acid-proof cements are used for cementing troughs or other objects intended to hold acid.

2. — For Galvanoplasty. — An oaken trough, close made, will last from 12 to 15 years if coated with Burgundy pitch, 1,500 grams; old gutta percha in shreds, 250 grams; pounded pumice, 750 grams. Melt the gutta percha, mix with the pumice and add the pitch. A hot iron passed over the surface smooths it and assists adhesion. The box resists sulphate of copper baths, but not cyanide.

3.—Melt together pitch, 1 part; rosin, 1 part, and plaster of paris (perfectly dry), 1 part.

AQUARIUM CEMENTS

1.—Whiting, 6 parts; plaster of paris, 3 parts; white beach sand, 3 parts; litharge, 3 parts; powdered rosin, 1 part. Mix thoroughly and make into a putty with the best coach varnish. Leave the glass a week before disturbing.

2.—Linseed oil, 3 oz.; tar, 4 oz.; rosin, 1 lb.; melt together over a gentle fire. If too much oil is used, the cement will run down the angles of the aquarium; to obviate this it should be tested before using by allowing a small quantity to cool under water; if not found sufficiently firm, allow it to simmer longer or add more tar and rosin. The cement should be poured in the corners of the aquarium while warm (not hot). This cement is pliable and is not poisonous.

Marble, To Cement

1.—Melt together 8 parts of rosin and 1 of wax; when melted, stir in 4 or 5 parts of plaster of paris. The pieces to be joined should be made hot.

2.—Procure a small piece of quicklime fresh from a newly burnt kiln, slake with the white of an egg, wash the fractured parts quite clean, and apply.

3.—Soak plaster of paris in a saturated solution of alum, bake in an oven, reduce it to a powder, mix with water, and apply; it sets like granite.

4.—Mix 12 parts of Portland cement, 6 parts of slaked lime, 6 parts of fine sand and 1 part of infusorial earth, and make up into a thick paste with silicate of soda. The object to be cemented does not require to be heated. It sets in 24 hours, and the fracture cannot be readily found.

Keene's Marble Cement.—Baked gypsum or plaster of paris, steeped in a saturated solution of alum, and then recalcined and reduced to powder. For use, mix up with water the same as plaster of paris. This important cement will not stand the weather, but is admirably adapted for applying as a stucco.

CASEIN CEMENTS

1.—Casein is used for a number of cements which are useful, and, if prepared from pure casein, are very permanent. The cements of casein with lime are particularly recommended. Pure casein is prepared in the following way: Skim the milk carefully until there is not a trace of cream. Let it stand in a warm place until it curdles. Then pour it through a paper filter. Wash the casein remaining on the filter with rain water until the water shows no trace of free acid. Tie the casein in a cloth, and

boil in water to remove all fat. Spread on blotting paper, and dry in a moderately warm place. It will shrivel up in a hornlike mass.

2.—A solution of casein in a concentrated aqueous solution of borax, made with cold water, makes a very tenacious cement.

3.—Casein, in powder, 5 av. oz.; quicklime, in powder, 1 av. oz.; camphor, in powder, 120 grams. Mix. This powder to be made into a cream with sufficient water before using.

4.—Casein, in powder, 2 av. oz.; borax, in powder, 1 av. oz. Mix. Made into a paste with water when required.

CELLULOID

1.—Make a mixture composed of 3 parts of alcohol and 4 parts of ether; keep in a well corked bottle, and when celluloid articles are to be mended, paint the broken surfaces over with the alcohol and ether mixture until the surfaces soften; then press together and bind, and allow to dry for at least 24 hours.

2.—Dissolve 1 part of gum camphor in 4 parts of alcohol; dissolve an equal weight of shellac in such strong camphor solution. The cement is applied warm, and the parts united must not be disturbed until the cement is hard.

GLASS, PORCELAIN, CROCKERY, CEMENTS

1.—An excellent cement for glass or earthenware is made as follows: Gum shellac, 2 parts; Venice turpentine, 1 part; fuse together in an iron pot, and when partially cool form into sticks. When wanted for use, melt near a gentle heat. Care must be taken while fusing the materials to keep the vessel closed, as the turpentine is very inflammable. Or: Litharge, 2 parts; unslaked lime and flint glass, of each, 1 part; pulverize separately, and mix. To use it, wet with old drying oil.

2.—Strong gum arabic solution, 8 1-3 oz., to which a solution of 30 gr. sulphate of aluminum, dissolved in 2-3 oz. of water, is added.

3.—Stick Cement.—a.—Melt together, sulphur, 6 parts; white Burgundy pitch, 4 parts; shellac, 1 part; elemi, 2 parts; mastic, 2 parts; powdered kaolin, passed through a very fine sieve, 6 parts. Before applying, the surfaces to be joined must be carefully heated.

b.—Best and purest gum arabic is put into a small quantity of water, and left till next day, when it is of the consistency of treacle. Calomel (mercurous chloride or subchloride of mercury, poison) is then added to make a sticky mass, and well mixed on a glass plate with a spatula. No more is to be made than that required for immediate use. The cement hardens in a few hours, but it is better to leave it for a day or two.

Glass, Cements for

1.—India rubber, 10 parts; chloroform, 6 parts; mastic, 2 parts. This size is also good for making glass adhere to other hard surfaces.

2.—Delicate glassware, such as Venetian glass, can be cemented with best fish glue, applied hot and afterward tied well.

3.—Best gelatine, 100 parts, dissolved by warming in 150 parts of 96% acetic acid; then add 5 parts of ammonium bichromate in fine powder. Keep away from light. When drying mended parts, expose directly to the sun.

Special Purposes

1.—Cap Cements.—These are so named because they are used to fix on parts of electrical or other apparatus to glass. They are very useful for many purposes, and should find a place in every laboratory and amateur's workshop. a.—Glue, best white, 11 oz.; white curd soap, 1 oz.; plaster of paris, 3¼ lb.; water, ½ gal. The glue is put to soak overnight in just enough of the water to well cover it. In the morning (or when properly softened) it is dissolved, together with the soap, in the rest of the water, previously heated to boiling. When a quantity of the cement is required, a sufficient quantity of the plaster of paris is mixed up quickly with enough of the warm liquid to form a smooth thin paste. This paste must be used at once, as it soon sets or hardens. When hardened it is impervious to coal oil.

b.—Equal weights of red lead and white lead used for chemical and electrical purposes. For cementing glass tubes, necks of balloons, etc., into metal mountings. This is preferable to white lead alone, and may be depended on for temperature up to 212°.

2.—Chemical Cement.—a.—A good cement for chemical and electrical apparatus may be prepared by mixing 5 lb. of rosin, 1 lb. of wax, 1 lb. of red ocher and 2 oz. of plaster of paris, and melting the whole with moderate heat.

b.—Yellow wax, 4 parts; common turpentine, 2 parts; Venetian red (well dried), 1 part; melted together. Used as a temporary stopping or lute for the ends or joints of tubes which are not exposed to much heat, as in alkalimetry.

3.—Enamel and Porcelain Letters to Glass.—a.—Copal varnish, 15 parts; drying oil, 5 parts; turpentine, 2 parts; liquified marine glue, 5 parts; melt in a water bath, and add slaked lime, 10 parts.

b.—Rosin, 22 parts; burnt umber, 4 parts; calcined plaster, 2 parts; boiled oil, 1 part.

4.—Lenses.—In those of foreign make and arborescent appearance is occasionally to be seen between the elementary parts of which the lens is composed. This arises from the drying or shrinking of the balsam with which it is cemented. To remedy this unset the lens, place it in warm water, which may be still further heated till the balsam softens, separate the components, and clean with ether, benzole or turpentine. Next place a drop of pure balsam on the center of the concave surface and gently press the convex one down upon it until the balsam spreads and oozes out at the edges. Then apply a gentle heat until the balsam is found to have been hardened.

LEATHER CEMENTS

1.—A good cement is gutta percha dissolved in bisulphide of carbon until it is of the thickness of molasses; the parts to be cemented must first be well thinned down, then pour a small quantity of the cement on the parts to be cemented, spreading it well so as to fill the pores of the leather; warm the parts over a source of heat for about ½ minute, apply them quickly together and press hard. The bottle containing the cement should be tightly corked and kept in a cool place.

2.—This is made by mixing 10 parts of bisulphide of carbon with 1 part of oil of turpentine and then adding enough gutta percha, cut into small pieces, to make a tough, thickly flowing liquid. One essential prerequisite to a thorough union of the parts consists in freedom of the surfaces to be joined from grease. This may be insured by laying a cloth upon the part to be joined and applying a hot iron for a time. The cement is then applied to both pieces, the surfaces brought in contact and pressure applied till the joint is dry.

3.—This glue, though rather complex in composition, gives good results. Eight oz. of rye whisky are diluted with 8 oz. of water, and the mixture is made into a paste with 2 oz. of starch, ¾ of an oz. of good glue are dissolved in the same amount of water, and equal amount of turpentine is added, and the mixture and the paste are combined.

4.—Strong glue, 50 parts; water, sufficient quantity; turpentine, 2 parts; starch paste, 100 parts. Dissolve the glue over the fire in the water; add the turpentine, stir up well and mix with the starch paste while hot.

5.—Amalgamate by heat gutta percha, 100 oz.; Venice turpentine, 80 oz.; shellac, 8 oz.; India rubber, 2 oz.; liquid storax, 10 oz.

6.—Gutta percha, 1 lb.; India rubber, 4 oz.; pitch, 2 oz.; shellac, 1 oz.; linseed oil, 2 oz., melted together; it hardens by keeping and needs remelting for use.

7.—Best glue, 2 lb.; water, 3 pt. Dissolve by the aid of heat, and when the solution has become thick add Venice turpentine, 3¼ oz.; liquified carbolic acid, 80 min. On cooling this cement congeals to a gelatinous mass, which is then to be cut in strips and spread upon tin plates to dry. For use the cement is melted with the addition of a little vinegar and applied to the freshly cut leather and the points pressed between warm iron plates for 15 minutes.

8.—Gutta percha, 100 parts; black pitch or asphaltum, 100 parts; oil of turpentine, 15 parts. Mix. It is used hot.

9.—Belting.—Take of common glue and American isinglass, equal parts; place them in a boiler and add water sufficient to just cover the whole. Let it soak 10 hours, then bring the whole to a boiling heat, and add pure tannin until the whole becomes ropy or appears like the white of eggs. Apply it warm. Buff the grain off the leather where it is to be cemented, rub the joint surfaces solidly together, let it dry a few hours and it is ready for practical use, and if properly put together it will not need riveting, as the cement is nearly all of the same nature as the leather itself.

10.—Shoemakers' Cement. — a. — Dissolve gutta percha in chloroform to the consistency of honey. Heat the surfaces to which it is to be applied and press together.

b.—An elastic cement for patching shoes (invisible patches), attaching soles that have been "started," etc. Dissolve 10 parts of gutta percha in 100 parts of benzol, pour the solution into 100 parts of linseed oil varnish and stir until a homogeneous mixture is obtained. To make a firm and nicely appearing job the patch should be chamfered down at the edges with a keen knife and the shoe leather trimmed away around the break so as to present a clean, fresh surface to the cement.

MECHANIC'S CEMENTS

Turner's Cement.—1.—Rosin, ½ oz.; pitch, ½ oz.; beeswax, 1 oz.; melted together, sufficient fine brick dust added to produce desired consistency.

2.—Rosin, 2 lb.; Burgundy pitch, 2 lb.; dried whiting, 2 lb.; yellow wax, 2 oz.; melted and mixed together.

3.—Black rosin, ½ lb.; yellow wax, 1 oz.; melted together and poured into a tin canister.

4.—Melt 1 lb. of rosin in a pan over the fire, and, when melted, add ¼ lb. of pitch. While these are boiling add brick dust until, by dropping a little on a cold stone, you think it hard enough. In winter it may be necessary to add a little tallow. By means of this cement a piece of wood may be fastened to the chuck, which will hold when cool; and when the work is finished it may be removed by a smart stroke with the tool. Any traces of the cement may be removed from the work by means of benzine.

METALS

1.—Melt over a water bath copal varnish, 30 parts; drying oil, 10 parts; turpentine, 6 parts; when melted add 20 parts slaked lime.

2.—Boiled linseed oil, 6 parts; copal, 6 parts; litharge, 2 parts; powdered white lead, 1 part.

3.—Slaked lime, 1 part; brick dust, 2 parts; boiled linseed oil, 3 parts. Make a thoroughly homogeneous mixture of the ingredients.

4.—Glycerine and litharge, stirred to a paste, harden rapidly and make a tolerable cement for iron upon iron, for two stone surfaces and especially for fastening iron in stone. This cement is insoluble and is not acted upon by strong acids.

Brass Joints

Unvulcanized rubber, 2 parts; gutta percha, 1 part; brass filings, 10 parts. Melt by the aid of heat.

Brass to Tin

To 20 parts of fine, reduced copper add sufficient sulphuric acid to make a stiff paste. To this add 70 parts of metallic mercury and work in, at the same time applying heat until the mass assumes a wax-like consistency. Warm or heat the plates to be united to about the same temperature, apply the mixture, hot, to each, then press together and let cool.

Copper to Sandstone

Take white lead, 30 parts; litharge, 3 parts; bole, 3 parts, and broken glass, 3 parts, and rub up with 2 parts linseed oil varnish.

Coppersmiths' Cement

Powdered quicklime mixed with bullock's blood; use at once.

Iron

1.—Graphite, 50 lb.; whiting, 15 lb.; litharge, 15 lb. Make to a paste with boiled oil.

2.—Make a putty of white lead and asbestos.

3.—Make a paste of litharge and glycerine. Red lead may be added. This also does for stone.

4.—Make iron filings to a paste with water glass.

5.—Sal ammoniac, 4 oz.; sulphur, 2 oz.; iron filings, 32 oz. Make as much as is to be used at once to a paste with a little water. This remark applies to both the following dry recipes:

6.—Mix iron filings, 180 oz.; lime, 45 oz.; salt, 8 oz.

7.—Mix iron filings, 140 oz.; hydraulic lime, 20 oz.; sand, 25 oz.; sal ammoniac, 3 oz.

Either of these last two mixtures is made into a paste with strong vinegar just before use.

Steam, Hot Water and Hot Air Boilers and Pipes.—1.—Take of coarsely powdered iron borings, 5 lb.; powdered sal ammoniac, 2 oz.; sulphur, 1 oz., and water sufficient to moisten it. This composition hardens rapidly, but if time can be allowed it sets more firmly without the sulphur. It must be used as soon as mixed and rammed tightly into the joint.

2.—Take sal ammoniac, 2 oz.; sublimed sulphur, 1 oz.; cast iron filings or fine turnings, 1 lb. Mix in a mortar and keep the powder dry. When it is to be used mix it with 20 times its weight of clean iron turnings, or filings, and grind the whole in a mortar; then wet it with water until it becomes of convenient consistency, when it is to be applied to the joint. After a time it becomes as hard and strong as any part of the metal.

3.—For stopping holes in castings or covering scars a useful cement may, it is said, be made of equal parts of gum arabic, plaster of paris and iron filings, and if a little finely pulverized white glass be added to the mixture it will make it still harder. This mixture forms a very hard cement that will resist the action of fire and water. It should be kept in its dry state and mixed with a little water when wanted for use.

4.—Hot Water Cistern.—To 4 or 5 parts clay, dried and pulverized, add 2

parts of fine iron filings free from oxide; peroxide of manganese, 1 part; sea salt, ½ part, and borax, ½ part. Thoroughly incorporate these in as fine a state as possible, reduce them to a thick paste with water and use immediately. It should then be exposed to heat, gradually increasing to almost a white heat. This cement resists heat and boiling water.

5.—Iron Putty.—The iron putty used for steam joints is made by mixing dry 2 parts of a good metallic paint; litharge, 1 part; fine iron borings, sifted, 3 parts, or for close joints, iron filings. Add boiled linseed oil and mix to the consistency of stiff putty.

6.—Leaks in Boilers. — Emergencies often arise when a leak must be stopped in a boiler while still under fire. The following preparation has been found serviceable: Mix well together powdered graphite, 6 parts; slaked lime, 3 parts; heavy spar (barytes), 8 parts, and thick linseed oil varnish, 8 parts, and apply in the ordinary way to the spots.

7.—Red Lead made into a paste with boiled linseed oil is also used for cementing the joints of metal pipes.

8.—Rust Cement.—Make a stiff paste with sal ammoniac, 2 parts; iron borings, 35 parts; sulphur and water, 1 part, and drive it into the joint with a chisel, or to 2 parts of sal ammoniac and 1 part flowers of sulphur add 60 parts of iron chips and mix the whole with water, to which 1-6 part vinegar or a little sulphuric acid is added. Another cement is made by mixing 100 parts of bright iron filings or fine chips or borings with 1 part powdered sal ammoniac and moistening with urine; when thus prepared, force into the joint. It will prove serviceable under the action of fire.

Isinglass

Isinglass solution, 100 parts, and nitric acid, 1 part. Stir the nitric acid evenly in a very thick isinglass solution and paint the metallic surfaces with this liquid. The surfaces must be firmly pressed together. The object of the nitric acid is to make the surfaces rough by corrosion; its use, however, is attended with the disadvantage that it hinders the drying of the cement. It is therefore necessary to expose the cemented metallic surfaces to a higher temperature for a time to hasten the drying.

Linseed Oil

Linseed oil and well slaked lime are made into a paste. Great pressure must be used.

Plumber's Cement

Black rosin, 1 part; brick dust, 2 parts; well incorporated by a melting heat.

METALS TO GLASS, MARBLE, PORCELAIN, STONE, ETC.

1.—One of the best cements for uniting glass to other substances consists of a mixture of gum and calomel. Its adhesive power is something marvelous. It is prepared by putting the very best and purest gum arabic into a small quantity of water and leaving it till next day, when it should be of the consistency of treacle. Calomel (mercurous chloride or subchloride of mercury) is then added in suitable quantity, enough to make a sticky mass, being well mixed on a glass plate with a spatula. No more is to be made than that required for immediate use. The cement hardens in a few hours, but it is wiser to leave it to itself for a day or two. To insure success it is necessary to use only the very best gum; inferior sorts are absolutely useless.

2.—One lb. of shellac, dissolved in 1 pt. of strong methylated spirit, to which is to be added 1-20 part of a solution of India rubber in carbon bisulphide.

3.—Take 2 oz. of a thick solution of glue and mix with 1 oz. of linseed oil varnish or 1 oz. of Venice turpentine. Boil together, agitating until the mixture becomes as intimate as possible. The pieces cemented should be clamped together for a space of 48 to 60 hours.

4.—Petroleum Cement. — a. — Dissolve 5 parts of shellac and 1 part of turpentine in 15 parts of petroleum. This cement is fairly elastic.

b.—A cement particularly adapted for attaching the brasswork to petroleum lamps is made by Puscher by boiling 3 parts rosin with 1 part of caustic soda and 5 parts of water. The composition is then mixed with half its weight of plaster of paris and sets firmly in ½ to ¾ of an hour. It is of great adhesive power and not permeable to petroleum, a low conductor of heat and but superficially attacked by hot water. Zinc white, white lead or precipitated chalk may be substituted for plaster, but hardens more slowly.

Brass to Glass

1.—Knead rosin soap with ½ the quantity of plaster of paris.

2.—Substitute zinc white for the plaster of paris or slaked lime, which causes it to harden much slower.

3.—Boil together caustic soda, 1 part; rosin, 3 parts; gypsum, 3 parts, and

water, 5 parts. The cement made in this way hardens in about ½ hour, hence it must be applied quickly. During the preparation it should be stirred constantly. Remember that all the ingredients used must be in a finely powdered state.

4.—Fresh beaten blood, 13 parts; slaked lime, 4 parts, and a little alum. This should be used immediately and applied with a brush. One or two coats will render any cloth waterproof.

Iron Articles in Stone

1.—Plaster of paris, 14 parts; iron filings, 2 parts. Mix and stir into a paste with water. This cement dries quickly.

2.—Mix into a paste with water 3 lb. plaster of paris and 1 lb. iron filings.

3.—Brick Dust Cement.—A new cement for securing iron to stone is described in some of the foreign papers. The cement is made by melting rosin and stirring in brick dust, which must be finely ground and sifted until a sort of putty is formed, which, however, runs easily while hot. In using, the iron is set into the hole in the stone prepared to receive it, and the melted putty poured in until the space is filled; then, if desired, bits of brick, previously warmed, may be pushed into the mass and a little of the cement thereby saved. As soon as the whole is cool the iron will be firmly held to the stone and the cement is quite durable and uninjured by the weather, while, unlike lead and sulphur, it has no injurious effect on the iron.

Metal Letters on Glass, Marble, Wood, etc.

1.—Copal varnish, 30 parts; linseed oil varnish, 10 parts; oil of turpentine, 10 parts; glue, 10 parts. Place the mixture in a water bath, to dissolve the glue, then add 20 parts slaked lime.

2.—Rosin, 4 to 5 parts; beeswax, 1 part; the whole melted together. A little powdered plaster is often added.

3.—Fine litharge, 2 parts; white lead, 1 part; copal, 1 part; boiled linseed oil, 3 parts; the whole is triturated together. Dissolve by heat.

4.—For joining metallic surfaces where soldering is inconvenient recourse may be had to a composition formed in the following way: Pure and finely divided copper, such as that obtained by the reduction of sulphate of copper with zinc clippings, 20 to 36 parts, according to the degree of hardness desired in the cement, dissolved in a sufficient quantity of sulphuric acid to make a thick paste; with this is incorporated by trituration in a mortar, mercury, 70 parts. The mass is soft, but hardens at the end of some hours. For use it is heated to 212° F. (100° C.), and powdered in an iron mortar heated to 302° F. (150° C.); it then assumes the consistency of wax and is harder in proportion, as it contains more copper.

Tiles to Iron

Use a gutta percha cement, made by melting together in an iron pan 2 parts of common pitch and 1 part of gutta percha. Stir them well together until thoroughly incorporated and then pour the liquid into cold water. When cold it is black, solid and elastic, but it softens with heat, and at 100° F. is a thin fluid. Also try bedding in plaster of paris.

Tin to Wood

Melt in a thick-walled iron vessel 1 part of yellow wax, stir in 2 parts of gutta percha chips to complete dissolution and dissolve therein 2 parts of shellac and 0.1 part of boiled linseed oil. After the mass has cooled off pour it upon a somewhat moistened metal or stone plate; next knead and shape into bars. Dry well the wooden or tin parts to be cemented and apply evenly the melted cement on the wood and tin. Press the articles together moderately and allow them to remain for 24 hours. To matt the tin by scouring with emery is advantageous. The process should not be conducted in too cool a place.

METALS TO LEATHER, CLOTH, WOOD, ETC.

Cloth to Metal

1.—Cloth can be cemented to polished iron shafts by first painting the shafts with a coat of best white lead paint. After the paint has dried hard coat with Russian glue, dissolved in water acidulated with a little vinegar or acetic acid.

2.—Starch, 20 parts; sugar, 10 parts; zinc chloride, 1 part; water, 100 parts. Mix the ingredients and stir until a perfectly smooth liquid results entirely free from lumps, then warm gradually until the liquid thickens.

3.—Cloth on Iron Rolls.—There is nothing better for this purpose than good glue, to which has been added tannin until the glue becomes ropy.

Cork to Metal

In fastening cork to iron and brass, even when these are lacquered, a good sealing wax containing shellac will be found to serve the purpose nicely. Wax prepared with rosin is not suitable. The

cork surface is painted with the melted sealing wax. The surface of the metal is heated with a spirit flame entirely free from soot until the sealing wax melts when pressed upon the metallic surface. The wax is held in the flame until it burns, and it is then applied to the hot surface of the metal. The cork surface painted with sealing wax is now held in the flame, and as soon as the wax begins to melt the cork is pressed firmly on the metallic surface bearing the wax.

Leather to Metal

1.—Melt together equal parts asphalt and gutta percha and apply hot under a press.

2.—Leather to Iron.—Paint the iron with some kind of lead color, say white lead and lampblack. When dry cover with a cement made as follows: Take 1 oz. of the best glue, soak it in cold water till soft, then dissolve it in 1½ fl. oz. vinegar with a moderate heat, then add 1-3 of the bulk of white pine turpentine, thoroughly mix and by means of the vinegar make it of the proper consistency to spread with a brush and apply it while hot; draw the leather on quickly and press it tightly in place. If a pulley, draw the leather round tightly, lap and clamp.

3.—Leather to Iron Pulleys.—Cut your leather roughly to shape, allowing about 1 in. per 12 in. in the width of the pulley. Then soak your leather in water until it is wet through. Now stretch it well in the direction of the circumference of the pulley and cut it to exact shape and length. It should next be sewn up, butt to butt, with a shoemakers awl and thread, and the leather, having been stretched in the direction of circumference only, will, as it gets dry, have a tendency to resume its former shape, thereby shortening in circumference and "clip" to the pulley. A shallow groove might be made for the stitches to sink down in.

Paper to Iron Pulleys

Scratch the face of the pulley with a rough file thoroughly, so that there are no bright or smooth places. Swab the surface with a solution of nitric acid, 1 part; water, 4 parts (for 15 minutes); then wash with boiling hot water. Having prepared a pot of the best tough glue, stir into the glue ½ oz. of a solution of strong tannic acid, oak bark or gallnuts, as convenient to obtain, to a quart of thick glue; stir quickly while hot and apply to the paper or pulley as convenient; draw the paper as tightly as possible to the pulley, overlapping as many folds as may be required. By a little management and moistening of the paper it will bind very hard on the pulley when dry and will not come off or get loose until it is worn out. Use strong hardware wrapping paper.

Wood to Metal

1.—Mix together carpenter's glue, 4 parts; Venice turpentine, 1 part.

2.—Iron may be cemented in wood by dropping in the recess prepared in the latter a small quantity of a strong solution of sal ammoniac. This causes the iron to rust, rendering it very difficult to extract.

3.—Litharge and Glycerine Cement.—A cement made of very finely powdered oxide of lead (litharge) and concentrated glycerine unites wood to iron with remarkable efficiency. The composition is insoluble in most acids, is unaffected by the action of moderate heat, sets rapidly and acquires an extraordinary hardness.

4.—Wood and Pasteboard to Metal.—Dissolve 50 grams of lead acetate together with 5 grams of alum in a little water. Make a separate solution of 75 grams of gum arabic in 2 l. of water, stir in this 500 grams of flour and heat slowly to boiling, stirring the while. Let it cool somewhat and mix with it the solution containing the lead acetate and alum, stirring them well together.

RUBBER

Carbon bisulphide is the solvent most commonly employed where it is desired to make a solution of rubber. Chloroform is also widely used for this purpose, but it is more expensive. With regard to benzine, benzol, gasoline and naphtha, considerable confusion exists, the names being loosely applied to a number of hydrocarbon compounds of petroleum derivatives of varying composition. The benzine of the U. S. Pharmacopœia is the liquid intended in nearly all the published formulas for rubber solutions. This distillate of petroleum differs from either gasoline or naphtha in being more volatile and explosive. It is characterized by a strong odor resembling that of petroleum, but much less disagreeable.

Rubber cements are very common and very useful, but great care should be taken in their preparation to guard against fire; they should not be prepared at night, as the carbon bisulphide, naphtha or chloroform is very inflammable. Vessels which are used to digest the rubber should be closed and, if possible,

put out of doors. If heat is required, use a sand or hot-water bath; on no account bring near a fire.

To repair the lacerated article, wash the hole over with the cement, then place a piece of linen dipped in it over the gap; as soon as the linen adheres the cement is applied as thickly as required.

1.—Caoutchouc, 1 part; mastic, 7 parts; chloroform, 50 parts. Mix and let stand until dissolved (which will require several weeks).

2.—Gutta percha, in pieces, 1 av. oz.; carbon bisulphide, 8 fl. oz.; rosin, 40 gr. Mix and dissolve.

Hard Rubber

1.—Dissolve bleached gutta percha in carbon bisulphide. Cement and when dry brush over carbon bisulphide in which sulphur has been dissolved.

2.—Equal parts of pitch and gutta percha are melted together and linseed oil is added, which contains litharge. Melt until all are well mixed, use no more of the linseed oil than necessary. Apply warm.

3.—Bisulphide of carbon, 26 parts; gutta percha, 2 parts; caoutchouc, 4 parts; fish glue, 1 part. Clean the surface of fissure or parts to be united very carefully and apply the cement. The edges of the rent should be kept to gether by means of thread and the article left to dry. At the end of from 24 to 36 hours the binding thread may be removed and the cement which may have squeezed out of the fissure cut away. It should be noted that the bisulphide of carbon is extremely inflammable and should be kept away from all exposed lights or fires.

4.—Gutta percha, 16 parts; caoutchouc, 4 parts; pitch, 2 parts; shellac, 1 part; linseed oil, 2 parts. Melt together.

Rubber Boots and Shoes

1.—Caoutchouc, 62 parts; chloroform, 250 parts; mix, and dissolve. Then take caoutchouc, 60 parts; rosin, 24 parts; oil of turpentine, 250 parts. Mix, and dissolve. When complete solution has taken place in both cases, mix the 2 solutions and agitate until homogeneous. Use cold, and apply a portion of the cement to each surface to be joined.

2.—Dissolve 1 dr. of gutta percha in 1 oz. of bisulphide of carbon, filter through coarse filter paper, add 15 gr. of pure rubber, rub the whole smooth with a palette knife, taking care to do it quickly. If necessary, thin with bisulphide of carbon. Keep it away from fire or light, as it is volatile and inflammable.

Rubber Hose

The damaged part, previously well cleaned and dried, is painted over with hot oil of turpentine. A thin sheet of gutta percha, softened by heat, is put around it so that the edges meet, and is pressed against the hose with a knife blade. The edges are finally cemented together by touching the seam with a moderately hot iron rod.

Rubber to Wood, Glass, Metal, etc.

1.—Soak powdered shellac in 10 times its weight of strong water of ammonia, whereby a transparent, gelatinous mass is produced. Melt by placing the vessel in hot water. When using the cement the surfaces of the rubber and the substance to be cemented are coated with the liquid mass and then firmly pressed together. So soon as the ammonia has evaporated the rubber hardens, and the joints are as firm as the rubber.

2.—Hard Rubber to Metal.—Make a thin solution of glue, and gradually add pulverized wood ashes till you have a stiff varnish. Use this cement hot.

Rubber, to Fasten to Metal.—This may be done by employing a cement which fastens alike well to the rubber and to the metal or wood. Such cement is prepared by a solution of shellac in ammonia, best made by soaking pulverized gum shellac in 10 times its weight of strong ammonia, when a shining mass is obtained, which in 3 or 4 weeks will become liquid without the use of hot water. This softens the rubber, and becomes, after volatilization of the ammonia, hard, and impermeable to gases and fluids.

Tire to Rim, Leather

Carbon bisulphide, 19 parts; oil of turpentine, 1 part; gutta percha, cut in small pieces, q. s. Mix the turpentine and carbon bisulphide, and add sufficient gutta percha, under frequent agitations, or rubbing up, until a thick paste is obtained. To make a good joint, all fatty and greasy matter must be got rid of.

Tire to Rim, Rubber

A good, thick shellac varnish, with which a small amount of castor oil has been mixed, will be found a very excellent rim cement. The formula recommended by Edel is as follows:

1.—Shellac, 1 lb.; alcohol, 1 pt.; mix, and dissolve, then add castor oil, ½ oz. The castor oil prevents the cement from becoming hard and brittle.

2.—Melt together, at a gentle heat, equal parts of gutta percha and asphalt. Apply hot. Sometimes a small quantity each of sulphur and red lead are added (about 1 part of each to 20 parts of cement).

WOOD TO WOOD, METAL, GLASS, STONE

1.—Ash Cement.—Warm good cabinet-makers' glue with water to the consistency necessary to connect wooden objects; then add enough sifted ashes to bring it to the thickness of a varnish. Then cement should be applied to the surfaces of the objects to be united when warm, and then they should be pressed together tightly. After cooling and drying, the surfaces are so strongly united as to require great force to separate them. Grinding stones fastened on wood, and handles to painters' stones for grinding colors, have been used for more than a year without exhibiting any appearance of fracture.

2.—Cloth or Leather to Table-tops.—Wheat flour, 2¼ lb.; powdered rosin, 4 tablespoonfuls; powdered alum, 2 tablespoonfuls; heat, and mix to a stiff consistency.

3.—Emery to Wood.—Melt together equal parts of shellac, white rosin and carbolic acid, in crystals; add the last after the others are melted. The effect of the carbolic acid is surprising.

4.—Filling Cement for Holes in Wood. a.—Mix together rosin and turpentine, 1 pt. each, over a water bath, and add 2 pt. common burnt ocher. Have the work dry.

b.—Put any quantity of fine sawdust of the same kind of wood into an earthen pan, and pour boiling water on it; stir it well, and let it remain for a week or 10 days, occasionally stirring it; then boil it for some time, and it will be of the consistency of pulp or paste; put it into a coarse cloth and squeeze all the moisture from it. Keep for use, and, when wanted, mix a sufficient quantity of thin glue to make it into a paste; rub it well into the cracks, or fill up the holes in your work with it. When quite hard and dry, clean the work off, and, if carefully done, you will scarcely discern the imperfection.

Benzine and Petroleum, Cement to Resist.—It has quite recently been discovered that gelatine mixed with glycerine yields a compound liquid when hot, but which solidifies on cooling, and forms a tough, elastic substance, having much the appearance and characteristics of India rubber. The two substances united form a mixture entirely and absolutely insoluble in petroleum or benzine, and the great problem of making casks impervious to these fluids is at once solved by brushing or painting them on the inside with the compound. This is also used for printers' rollers and for buffers of stamps, as benzine or petroleum will clean them when dirty in the most perfect manner, and in an incredibly short space of time. Water must not be used with this compound.

Bisulphide of Carbon, Cement Impervious to.—Best quality of white glue with 10% of molasses added.

Cloth, Cement for.—1.—Use thin sheet gutta percha, which can be purchased of the manufacturers, especially for tailors' use. Place a piece of the tissue between the layers of cloth to be cemented, and press with a hot iron. This causes the cloth to firmly adhere on account of the melting of the gutta percha.

2.—Gutta percha, 16; caoutchouc, 4; pitch, 2; shellac, 1; linseed oil, 2.

Collodion Cement.—Powdered nitrate of potash, 1 dr.; concentrated sulphuric acid, 1½ dr.; carded cotton, 5 dr. The nitrate of potash and the acid should be mixed in a porcelain capsule, gradually add the cotton, and stir for 5 minutes. Wash it thoroughly in clear water, pull it apart, and dry—not near the fire, as it is a species of guncotton. Dissolve in rectified sulphuric ether and a little alcohol. It will form a transparent, colorless and strong adhesive cement.

Cutler's Cement.—1.—For fastening blades of dinner knives in ivory handles. Consists of rosin, 4 parts; beeswax, 1 part; plaster of paris or brick dust, 1 part. Fill the hole in the handle with the cement, heat the tang of the blade, crowd in, and remove superfluous cement.

2.—Rosin, 16 oz.; hot whiting, 16 oz.; wax, 1 oz.

3.—Pitch, 5 parts; wood ashes, 1 part; hard tallow, 1 part; melted together.

4.—Black rosin, 4 lb., melted with 1 lb. beeswax, and 1 lb. red-hot whiting added.

Davy's Cement. — Davy's universal cement is made by melting 4 parts common pitch with 4 parts gutta percha in an iron vessel, and mixing well. It must be kept fluid, under water, or in a dry, hard state.

Diamond Cement.—The following formula will be found useful in repairing china, glass, wood, leather, etc.: Isinglass, 240 gr.; mastic, 120 gr.; gum ammoniac or galbanum, 60 gr.; alcohol, 4 fl. oz.; water, 4 fl. oz. Soak the isinglass in the water for 24 hours; evaporate on a water bath to 2 fl. oz.; then add

2 fl. oz. of alcohol; strain; add the mastic, dissolved in the remaining alcohol, and add the ammoniac by trituration, avoiding loss of alcohol as much as possible.

Flexible Cement.—Flexible cement is composed of white pitch and gutta percha, equal parts, mixed over a water bath. Many of the other gutta percha and rubber cements answer for flexible cements.

Gas Bags, Cement for.—Add 1 part of glycerine to very thick boiled glue. Fill the bag with air and apply while warm; if too sticky, strew it with a little powdered soapstone. For large rents use leather well covered with glue.

Gas Fitters' Cement.—Melt together 4½ parts rosin (by weight), 1 part beeswax; then stir in 3 parts Venetian red, and pour into molds made of oiled paper or iron.

Gases, To Resist.—1.—Clay is dried, powdered, sifted, placed in an iron mortar, and incorporated with drying oil, added gradually, the whole being well beaten up till the mass assumes the consistency of a fine paste. It should be preserved under a coating of oil, to prevent it drying up. It resists the action of corrosive gases, but inconveniently softens by exposure to heat.

2.—Plaster of paris, mixed with water, milk, or weak glue. Stands a dull-red heat.

Insulating Cement.—Shellac, 5 parts; rosin, 2 parts; Venice turpentine, 1 part; yellow ocher, 3 parts.

Insulating Tapes, Cement for.—1.—Pure gum rubber, dissolved in turpentine, with the addition of 5% of raw linseed oil.

2.—Yellow pitch, 8 parts; beeswax, 2 parts; tallow, 1 part.

Litharge Cement.—Litharge, 1 oz.; plaster of paris, 1 oz.; finely powdered rosin, 1-3 oz.; mix thoroughly, and make into a paste with boiled linseed oil to which driers have been added. Beat it well, and let it stand 4 or 5 hours before using. Soda silicate and chalk make a good cement.

Mica, Cement for.—A colorless cement for joining sheets of mica is prepared as follows: Clear gelatine is softened by soaking it in a little cold water, and the excess of water is pressed out by gently squeezing it in a cloth. It is then heated over a water bath until it begins to melt, and just enough hot proof spirit (not in excess) stirred in to make it fluid. To each pint of this solution is gradually added, while stirring, ¼ oz. of gum ammoniac and 1 1-3 oz. of rectified spirit. It must be warmed to liquify it for use, and kept in stoppered bottles when not required. This cement, when properly prepared, resists cold water.

Opticians' Cement.—1.—Shellac, softened with rectified spirit or wood naphtha. For fine work.

2.—Beeswax, 1 oz.; rosin, 15 oz. Melt, and add whiting (previously made red hot, and still warm), 4 oz.

Signs, Filling, Cement for.—Melt together, in a clean iron pot, 2 parts each of best asphaltum and gutta percha; stir well together, and then add 1 part of gum shellac in fine powder. It may be used hot and mixed with smalt, vermilion, or other pigment, if desired.

Zinc White Cement.—1, mastic; 2, dammar; 3, sandarac; 4, Venetian turpentine; 5, turpentine; 6, benzol; 7, zinc white. 1, 2 and 3, powdered, are mixed in a well-corked bottle with 4, 5 and 6; shake well occasionally; after several days filter, and triturate in a mortar with zinc white in q. s. Dilute, if necessary, with benzol.

GLUE

Glue is a cement used for joining pieces of wood together, and has for its chief constituent a substance called gelatine, obtained from the cuttings of hides, skins, tendons and other refuse parts of animals, as well as from cuttings of leather and parchment, which, after being well soaked in milk of lime, to dissolve any blood, flesh or fat, are thoroughly washed in a stream of water to remove the lime. The material is then boiled in water until the required adhesive strength is obtained, when the liquid is run off into a cistern, and clarified with powdered alum, which precipitates in the form of sulphate any lime that may remain, as well as other impurities. Before cooling it is drawn off into molds, and is then in the form of size, which, when cut into slices, and dried in the air, hardens into glue.

Hints About Glue

1,—Good glue should be a light brown color, semi-transparent, and free from waves or cloudy lines. Glue loses much of its strength by frequent remelting; therefore, glue which is newly made is preferable to that which has been reboiled. The hotter the glue the more force it will exert in keeping the joined parts glued together. In all large and long joints it should be applied immediately after boiling. Apply pressure until it is set or hardened. Glue, being an animal substance, must be kept sweet. To do this keep it cool after it is once dissolved, and not in use. In all cases keep

the glue kettle clean and sweet, by cleaning it often. Good glue requires more water than poor. The best glue will require from one-half to more than double the water that is required with poor glue, which is clear and red; the quality can be discovered by breaking a piece. If good, it will break hard and tough, and will be irregular on the broken edge. If poor, it will break comparatively easy, leaving a smooth, straight edge. In dissolving glue, it is best to weigh the glue, and weigh or measure the water; otherwise, there is a liability of getting more glue than the water can properly dissolve. It is a good plan, when once the quantity of water that any sample of glue will take up has been ascertained, to put the glue and water together at least 6 hours before heat is applied, and if it is not soft enough then, let it remain longer in soak, for there is no danger in letting good glue remain in pure water, even for 48 hours. The advantage of frozen glue is that it can be made up at once, on account of its being so porous. Frozen glue of same grade is as strong as if dried. If glue is of first-rate quality, it can be used on most kinds of woodwork very thin, and will make the joint as strong as the original. White glue is made white by bleaching.

Liquid Glue

1.—Glue, cut in small pieces, 6 parts; water, 16 parts, poured over it and allowed to stand for a few hours; add sulphate of zinc, 1½ parts; hydrochloric-acid gas, 1 part. Keep the mixture at a temperature of 175 to 190° F. for 10 or 12 hours. This glue may be used for joining all articles, even porcelain, glass, mother-of-pearl, etc. It does not congeal.

2.—Best white glue, 4 parts; lead carbonate, 1 part; rain water, 8 parts; alcohol, 1 part. Dissolve the glue in the water on a water bath, stirring constantly; then mix in the lead carbonate, add the alcohol, and continue the heat for a few minutes; lastly, pour into bottles while it is still hot.

3.—Take a wide-mouthed bottle, and dissolve in it 8 oz. best glue, in ½ pt. of water, by setting it in a vessel of water and heating until dissolved. Then add, slowly, 2½ oz. of strong aquafortis (nitric acid), 36° B., stirring all the while. Effervescence takes place under generation of nitrous acid. When all the acid has been added the liquid is allowed to cool. Keep it well corked, and it will be ready for use at any moment.

4.—Quick-Setting Glue Cements.—For paper, cloth, leather, wood, earthenware, etc.: (a) Soak 1 lb. of white fish glue 4 hours in 30 fl.oz. of cold water; (b) mix 4 oz. of dry white lead with 2 fl.oz. of hot water; (c) 4 oz. 90% alcohol. Dissolve (a) by aid of glue pot, then slowly add (b). Cook for about 10 minutes, then let cool to about 100° F. Now, with constant stirring, add (c). This cement sets in about 1 minute, due to the alcohol used. It is non-elastic, and extremely hard. For leather and cloth, if wanted pliable, add 2 to 4 oz. of glycerine, according to the elasticity desired. The above cement, without glycerine, and with the addition of 4 oz. of red lead, will stand a bath in hot oil without frying out.

5.—Russian Liquid Glue.—Soften 50 parts of best Russian glue in 50 parts of warm water; add, slowly, from 2¾ to 3 parts of aquafortis and 3 parts of powdered sulphate of lead.

6.—Spaulding's Glue.—Soak the glue in cold water, using only glass, earthen or porcelain dishes. Then by gentle heat dissolve the glue in the same water, and pour in a small quantity of nitric acid, sufficient to give the glue a sour taste, like vinegar, about 1 oz. to every pound of glue.

Special Glues

1.—Elastic Glue.—a.—Best glue, 7 av.oz.; glycerine, 16 fl.oz.; water, enough Pour on the glue more than enough water to cover, allow to macerate for several hours, then decant the greater portion of water; apply heat until the glue is dissolved, and add the glycerine. If the mixture is too thick, more water may be added. It may be colored by means of an aniline dye, dissolved in alcohol. The addition of a little calcium chloride also tends to prevent the glue from cracking. May be used for camera bellows.

b.—The following does not spoil: Dissolve good common glue in water, on the water bath, and evaporate the water down to a mass of thick consistency; add a quantity of glycerine equal in weight with the glue, after which continue the heating until all the water has been driven off; pour the mass out into molds or on a marble slab. This mixture answers for stamps, printer's rolls, galvano-plastic copies, etc.

2.—Ether Glue.—Dissolve glue in nitric ether. The ether will dissolve only a certain amount of glue, therefore the solution cannot be made very thick; it will be about the consistency of molasses, and is much more tenacious than glue made with hot water. It is improved by add-

ing a few bits of India rubber, cut into pieces about the size of a buckshot. Let the solution stand a few days, stirring frequently.

3.—Fireproof Glue.—Mix a handful of quicklime in 4 oz. of linseed oil, boil to a good thickness, then spread on tin plates in the shade, and it will become exceedingly hard, but may be easily dissolved over the fire, and used as ordinary glue.

4.—Frozen Glue.—The glue, while gelatinous, is sliced, placed on nets, and allowed to freeze by natural cold. Of course, the process can only be conducted in cold weather. The product is porous, and much more bulky than hard glue, but is a better article, as it dissolves more easily. It sells largely in New England, where it is preferred by buyers to the hard glue.

5.—Isinglass Glue.—Dissolve isinglass in water, and strain it through coarse linen. Then add a little alcohol, and evaporate to such a consistency that when cold it will be dry and hard. This will be found to be more tenacious than common glue, and therefore preferable in many cases.

6.—Marine Glue.—a.—Although now far from new, the extremely valuable marine glue of Jeffrey does not seem to be as well known in this country as it deserves. Prepared by dissolving 1 part of India rubber in crude benzine, and mixing with 2 parts of shellac, by the aid of heat. The waterproof character of this cement, in connection with its slight elastic flexibility, the ease with which it is applied when warm, and the promptness with which it sets, on cooling, make it a most useful substance in many applications to house construction and furniture, as well as on board ship, where it was originally intended to be chiefly employed.

b.—Caoutchouc, 1 oz.; genuine asphaltum, 2 oz.; benzole or naphtha, q. s. The caoutchouc is first dissolved by digestion and occasional agitation, and the asphaltum is gradually added. The solution should have about the consistency of molasses.

7.—Parchment Glue.—Parchment, 10 parts, is cut into small pieces, and boiled in 128 parts of water until the liquid is reduced to 80 parts. The decoction is filtered through linen, and evaporated over a gentle fire until it presents the required consistency.

8.—Powdered Glue, Soluble Cold.—Carbonate of potash, 1 part; alum, 1½ parts; ordinary glue or fish glue, 10 parts; water, 4 parts. The whole is mixed and boiled, dried by ordinary methods, and then pulverized. It is applicable to any use.

9.—Rubber Glue.—Take 1 lb. of glue, cover it with cold water in a vessel in which it can be heated, let it stand over night; then add 1 fl.oz. of glycerine, and apply heat; bring to the boiling point, and continue the boiling for about 15 minutes; take off the fire and add to it coloring matter, if desired, and pour into molds, from which remove when it has become rigid. Keep in a cool place; when used, apply gentle heat to soften, being careful never to bring to a boil.

10.—Stratena.—This well-known household cement is said to be prepared as follows: White glue, 6 parts, dissolved in 8 parts of acetic acid; this solution is added to another composed of 1 part of French gelatine in 8 parts of water. After mixing add 1 part of shellac varnish.

11.—Tungstic Glue.—Tungstic glue has been suggested as a substitute for hard India rubber, as it can be used for all the purposes to which the latter is applicable. It is thus prepared: Mix a thick solution of glue with tungstate of soda and hydrochloric acid. A compound of tungstic acid and glue is precipitated, which, at a temperature of 86 to 104° F., is sufficiently elastic to be drawn out into very thin sheets.

12.—Veneering Glues, Well Suited for Inlaying.—The best glue is readily known by its transparency, and being of a rather light brown, free from clouds and streaks. Dissolve this in water, and to every pint add ½ gill of the best vinegar and ½ oz. of isinglass.

MUCILAGES

1.—The best quality of mucilage in the market is made by dissolving clear glue in equal volumes of water and strong vinegar, and adding one-fourth of an equal volume of alcohol, and a small quantity of a solution of alum in water. The action of the vinegar is due to the acetic acid which it contains. This prevents the glue from gelatinizing by cooling; but the same result may be accomplished by adding a small quantity of nitric acid. Some of the preparations offered for sale are merely boiled starch or flour mixed with nitric acid to prevent the gelatinizing.

2.—A strong aqueous solution of reasonably pure dextrine (British gum) forms a most adhesive and cheap mucilage. Alcohol is usually employed as the solvent where the mucilage is to be used for gumming envelopes, postage stamps, etc., in order to facilitate the drying, and acetic acid is added to increase the mo-

bility of the fluid. The strong aqueous solution is more adhesive than that prepared with alcohol, for the reason that it contains a greater proportion of the gum. To prepare this, add an excess of powdered dextrine to boiling water, stir for a moment or two, allow to cool and settle, and strain the liquid through a fine cloth. The addition of a little powdered sugar increases the glossiness of the dried gum without interfering greatly with its adhesiveness. The sugar should be dissolved in the water before the dextrine is added.

3.—Add British gum (dextrine) to a quantity of hot water until a syrupy liquid is obtained; then add a few drops of clove oil, and cool for use.

4.—Dietrich recommends the following as equal to any gum arabic mucilage: Dextrine, 400 parts, stirred in 400 parts of water, diluted with 200 parts more of water; 20 parts of glucose and 10 parts of aluminum sulphate are added, and the mixture heated to about 195° F., when the mass will become transparent and thin.

5.—Brown dextrine, 1 lb.; acetic acid, 4 oz.; alcohol, 4 oz.; water, q. s. add 2 pt. Dissolve the dextrine in 1 pt. of boiling water, strain through Canton flannel; add the acetic acid, and when nearly cold add the alcohol, stirring thoroughly.

6.—Dextrine, 10 drams; glucose, ½ dram; in which is dissolved a solution of alum, 15 gr.; glycerine, 1 dr.; water, to make 2 oz.

7.—White dextrine, 6 oz.; dilute acetic acid, 1 oz.; oil of cloves, 10 drops; glycerine, 1 oz.; water, to make 16 oz. Mix the dextrine thoroughly with 6 oz. of cold water, add 8 oz. of boiling water, boil 5 minutes, stirring constantly; add hot water sufficient to make 14 oz. When it is cold add the acetic acid, oil of cloves and glycerine. The oil must be thoroughly mixed with the remainder.

Tragacanth Mucilage

1.—(a) Pulverized tragacanth, 1 oz.; glycerine, 4 fl.oz. (b) Boiling water, 16 fl.oz. Macerate the tragacanth with the glycerine in a glass mortar, then stir the paste into the boiling water. This makes a very thick mucilage; 32 fl.oz. of boiling water gives a medium, and 64 fl.oz. a thin paste. Tragacanth paste works very smooth, but is not very adhesive.

2.—Tragacanth, 1 av.oz.; gum arabic, 1 av.oz.; boiling water, 64 fl.oz.; carbolic acid, 1 fl.dr.

PASTES

1.—White dextrine (5 lb. or), 5½ lb.; water, at 160° F., 1 gal.; oil of wintergreen, 30 min.; oil of cloves, 30 min. Dissolve the dextrine in the water; after cooling, add the oils, pour into suitable bottles, cork, and then put in a cool place. In from 1 to 2 weeks the solution will have congealed. However, this "ripening" process may be expedited by exposing the bottles in an ice chamber to a temperature of about 40°. Formaldehyde as a preservative, in this instance, seems to be contraindicated, on account of its interference with the congealing process. This latter, the author is inclined to think, is the result of molecular changes in the dextrine, since after the solution once has set it may be liquefied in a water bath any number of times, and gelation will take place again within less than 24 hours. As little as 4 lb. of dextrine to 1 gal. of water may successfully be used, if desired. The author points out that the best-known of this class of library pastes is broadly covered by a patent, but he naturally asks, how a patent on a solution of dextrine in water can hold.

2.—Take 1 qt. of water and dissolve in it 1 teaspoonful of pure powdered alum. Stir into this enough flour to make a thick cream. Break up every little lump of flour until the mixture is smooth. Stir in next 1 teaspoonful of powdered rosin. Now pour in 1 cupful of boiling water. Stir it all well. When the mixture has thickened from cooking by the boiling water pour into an earthen vessel, cover it up, and keep it in a cool place; add a few drops of oil of cloves. Whenever you want to use any portion of it, take what you need and soften it with a little warm water. This will give you a perfect paste, clean, wholesome, and lasting. You will be surprised how little waste you will have. Should you need larger quantities, increase the proportions in proper ratio, doubling or trebling each ingredient, according to the magnitude of the business requiring it.—

3.—A solution of 2½ oz. of gum arabic in 2 qt. of warm water is thickened to a paste with wheat flour; to this is added a solution of alum and sugar of lead, 1½ oz. each, in water; the mixture is heated, and stirred about to boil, and is then cooled. It may be thinned, if necessary, with a gum solution.

4.—Flour, 4 oz.; powdered alum, ⅜ oz.; water, 1 qt.; oil of cloves, 20 drops; salicylic acid, 20 grams; alcohol, 2 dr. Mix the flour and alum, and sift; add water slowly until a perfectly smooth mixture results. Then cook over a steady fire or flame until the paste is made. As it is cooling add the clove oil and salicylic

acid, dissolved in the alcohol. Bottle in wide-mouthed bottles of 3 or 4 oz. each, cork well, and keep in a cool, dry place.

Postage Stamp Mucilage.—a.—Gum dextrine, 2 parts; water, 5 parts; acetic acid, 1 part. Dissolve by aid of heat, and add 1 part of 90% alcohol.

b.—Dissolve 1 lb. of gum dextrine in 1 pt. of boiling water, strain through flannel, and add 2 oz. of acetic acid. When nearly cold add 4 oz. of alcohol, stir constantly, and finally enough warm water to make 1 qt.

PUTTY

Putty may be considered as a cement. It is prepared by mixing fine whiting with linseed oil or linseed-oil varnish, the latter drying more quickly. The whiting should be passed through a sieve, the meshes being 42 threads to the inch. It should be dry before sifting, and be thoroughly incorporated with the oil, a tedious operation. Keep in oiled paper or under water. White lead is sometimes mixed with the putty. Color, if desired, with dry colors.

In the mixing of putty, use a stiff putty knife, and mix a large quantity at one time, as it improves with age. Pound your putty on the mixing block to expel the accumulated moisture that might be in the putty, also to make it tough and elastic. When you are pounding the putty add more dry pigment, if needed, as the more pigment you use the better the putty will be; but care should be taken not to use too much dry pigment, making your putty too dry. After mixing, put it in a clean can, and cover with clean water, for future use. A good putty knife for puttying gears may be made out of an old ½-inch wide spatula, cut off about 3 inches from the end of the ferrule.

To Soften Putty that has become hard, break the putty up in as small pieces as possible, put in an iron kettle with enough water to cover it, add a little raw linseed oil, and let it boil, and stir well while hot. The putty will readily absorb the oil; pour off the water, and when cool work it into shape, and it will be found good as new. This process is recommended by a large paint concern.

1.—Keg white lead, ½ lb.; dry white lead, ½ lb.; pale japan, 3 oz.; quick rubbing varnish, 3 oz. Quicken up with Reno's raw or burnt umber, keystone filler, or dry lampblack.

2.—Dry white lead, ⅝ part; keg white lead, ¼ part; mixed rough stuff, ⅛ part; rubbing varnish, ½ part; pale japan, ¼ part; turpentine, ¼ part.

3.—Black Putty for Irons.—Dry lampblack, 3 parts; dry white lead, 1 part; dry keystone filler, 1 part; rubbing varnish and japan, half and half.

4.—French Putty.—a.—Ruban prepares this substance by boiling 7 parts of linseed oil with 4 parts of brown umber for 2 hours; 5½ parts of chalk and 11 parts of white lead are then added, and the whole well mixed. This putty is very durable, and adheres well to wood, even though not previously painted.

b.—Gum arabic, 1 part; water, 2 parts; potato starch, 4 parts.

5.—Glazing Putty.—Keg white lead mixed with japan, 2 parts; rubbing varnish, 1 part; turpentine, 1 part; add a little dry color the same as the job is to be when painted. Make the paint a stiff paste or soft putty, the same as the job they are used on, by using consistency, and with a stiff brush spread this on the body and running parts.

6.—Soft Putty.—a.—Whiting, 10 lb.; white lead, 1 lb.; mix with the necessary quantity of boiled linseed oil, adding to it ½ gill of the best olive oil. The last prevents the white lead from hardening, and preserves the putty in a state sufficiently soft to adhere at all times, and not, by getting hard and cracking off, suffering the wet to enter, as is often the case with ordinary hard putty.

b.—A very strong putty is made of boiled oil and whiting, for exposed situations, as skylights, but is not adapted for keeping; it gets too hard.

c.—Putty for good inside work is improved by adding white lead.

d.—Another putty which requires to be made as wanted (as it gets hard almost immediately) is composed of red lead in powder, mixed with boiled oil and turpentine varnish, and is used for fronts of houses, or any place requiring a hard putty.

e.—Some manufacturers prepare an oil for the purpose of melting 20 lb. of rosin and mixing it with 90 lb. of linseed oil, the rosin being used for economy's sake.

f.—For some purposes a drying oil may be used with the whiting. This is made by mixing 1 gal. of linseed oil, 12 oz. of litharge, 1 oz. of sugar of lead, and 1 oz. of white vitriol; simmer for some time, allow to cool, and when settled draw it off.

FIREPROOF ADHESIVES

1.—Iron filings, 100 parts; hydraulic lime, 20 parts; quartz sand, 25 parts; sal ammoniac, 3 parts. These are formed into a paste with vinegar, and then applied. The cement is left to dry slowly before heating.

2.—Iron filings, 180 parts; lime, 45 parts; common salt, 8 parts. These are worked into a paste with strong vinegar. The cement must be perfectly dry before being heated. By heating it becomes stone hard.

3.—Linseed or almond meal, mixed to a paste with milk, lime water, or starch paste; resists a temperature of 500° F. (260° C.).

4.—Clay is puddled with water, and to it is added the greatest possible quantity of sand which has been passed through a hair sieve; the whole is worked up in the hands, and applied in coats more or less thick on vessels needing protection from the direct action of fire.

5.—Sifted manganese peroxide, 1 part; pulverized zinc white, 1 part; sufficient commercial soluble glass to form a thin paste. To be used immediately. Becomes very hard, and presents a complete resistance to red heat and boiling water.

6.—As a coating for glass vessels, to protect them from injury during exposure to fire, pipeclay and horse dung are made into a paste with water. This composition is applied by spreading it on paper; it is used by pipemakers, and will stand the extreme heat of their furnaces for 24 hours without damage.

Labels on Metal

1.—To attach paper to metal, and produce strong adherence, as desired for cards and labels, a small quantity of carbonate of potash should be added to the paste.

2.—Paint the label (which must be thoroughly dried) with collodion; apply a thin film of ordinary turpentine or of the lacquer with which the metal is covered, and press the label upon the surface of the container. If the vessels to be labeled are cylindrical in form, it is advantageous to add a few drops of castor oil to the lacquer used for fastening the paper.

3.—A label paste for paper or cloth to metals is composed of: Starch, 20 parts; sugar, 10 parts; zinc chlorite, 1 part; water, 200 parts. Mix the ingredients to a smooth paste, and heat cautiously until it thickens. Stir down, remove from the fire, and let cool.

WATERPROOF ADHESIVES

Cements

1.—Soak pure glue in water until it is soft, then dissolve it in the smallest possible amount of proof spirits by the aid of gentle heat. In 2 oz. of this mixture dissolve 10 grams of gum ammoniacum, and while still liquid add ½ dr. of mastic, dissolved in 3 dr. of rectified spirits. Stir well, and for use keep the cement liquefied in a covered vessel over a hot-water bath.

2.—A good waterproof cement may be made by mixing 5 parts of glue, 4 parts of rosin and 3 parts of red ocher with a little water.

3.—Shellac, 4 oz.; borax, 1 oz.; boil in a little water until dissolved, and concentrate by heat to a paste.

4.—Carbon bisulphide, 10 parts, and oil of turpentine, 1 part, are mixed, and as much gutta percha is added as will readily dissolve.

5.—Tar, 1 part; tallow, 1 part; fine brick dust, 1 part; the tar is warmed over a very gentle fire; the tallow is added, then the brick dust, and the whole is thoroughly mixed. It must be applied while hot.

6.—Good gray clay, 4 parts; black oxide of manganese, 6 parts; limestone, reduced to powder by sprinkling it with water, 90 parts; mixed, calcined, and powdered.

7.—Manganese iron ore, 15 parts; lime, 85 parts; calcined and powdered.

Both 6 and 7 require to be mixed with a little sand for use; thrown into water they harden rapidly.

8.—Fine, clean sand, 1 cwt.; powdered quicklime, 28 lb.; bone ash, 14 lb. Beaten up with water for use.

Glues

1.—Glue, 1 part; black rosin, 1 part; red ocher, ¼ part; mix with the least possible quantity of water. Or: Glue, 4 parts; boiled oil, by weight, 1 part; oxide of iron, 1 part.

2.—Glue, 1 lb., melted with the least quantity of water, and then mixed with black rosin, 1 lb., and red ocher, 4 oz.

3.—Glue, melted as above, and mixed with about ¼ of its weight each of boiled oil and red ocher.

4.—Ure.—Melted glue (of the consistency used by carpenters), 8 parts; linseed oil, boiled to varnish, with litharge, 4 parts; incorporate thoroughly together.

5.—Glue (melted as last), 4 parts; Venice turpentine, 1 part.

The first three dry in about 48 hours, and are very useful to render the joints of wooden casks, cisterns, etc., watertight; also to fix stones in frames. The last serves to cement glass, wood, and even metal, to each other. A good cement for fixing wood to glass may be made by dissolving isinglass in acetic acid, in such quantities that it becomes solid when cold. When applied let it be heated. They all resist moisture well.

CHAPTER III.

CLEANSING OF METALS

Aluminum

Cleansing Fluid.—A solution of 30 grams of borax in 1 l. of water containing a few drops of aqua ammonia.

Discoloration, Removing.—It is necessary simply to remove the foreign matter, and, fortunately, this can be very easily done. One way is to boil green fruits, particularly rhubarb, in a vessel. Another is to allow an oxalic acid solution—1 heaping teaspoonful of oxalic acid crystals to 1 gal. of lukewarm water—to stand in it overnight; then wash out the utensil thoroughly with clear hot water, rinse, and use as accustomed. But more to the point is the fact that, although a discolored utensil is unsightly in appearance, there is no danger whatever in using it. In other words, the impurities form no poisonous compound with the aluminum.

Polish.—1.—Aluminum is susceptible of taking a beautiful polish. This, unfortunately, is not white, like that of silver or nickel, but slightly bluish, like tin. The shade can be improved. First, the grease is to be removed from the object with pumice stone; then, for polishing, use is made of an emery paste mingled with tallow, forming cakes, which are rubbed on the polishing brushes. Finally, red rouge is employed with oil of turpentine.

2.—Stearic acid, 1 part; fuller's earth, 1 part; tripoli, 6 parts. To give the aluminum a natural, pure white color, dip it into a strong solution of caustic soda or potassa, and then into a bath of 2 parts of nitric acid and 1 part of sulphuric acid; thence into pure nitric acid, and finally into vinegar diluted with water. Rinse in running water, and dry in hot sawdust. Burnish with a bloodstone burnisher.

Brass and Copper Cleaning

1.—There are many substances and mixtures which will clean brass. Oxalic acid, muriatic acid, and several other acids, will clean brass very effectively; oxalic acid is the best, but the acids must be well washed off, the brass dried, and then rubbed with sweet oil and tripoli, otherwise it will soon tarnish again, Mixture to clean brass is: Soft soap, 1 oz.; rotten stone, 2 oz.

2.—Oxalic acid, 1 oz.; rotten stone, 2 oz.; sweet oil, 1½ oz.; spirits of turpentine, enough to make a paste. When used, a little water is added, and friction applied. If the brass is very dirty it requires a strong acid to make it bright; such is chromic acid, best prepared by mixing bichromate of potassa, sulphuric acid and water, equal parts of each. This makes the dirtiest brass bright and clear at once, but it must be immediately washed off with plenty of water, rubbed dry, and polished with rotten stone. There are no patents on any of these proceedings, and if there were, the patentees would not be sustained in their claims.

3.—Wash with rock alum, boiled in a strong lye in the proportion of 1 oz. to 1 pt.; polish with dry tripoli.

4.—The government method prescribed for cleaning brass, and in use at all the United States arsenals, is claimed to be the best in the world. The plan is to make a mixture of 1 part of common nitric acid and ½ part of sulphuric acid, in a stone jar, having also ready a pail of fresh water and a box of sawdust. The articles to be treated are dipped into the acid, then removed into the water, and finally rubbed with sawdust. This immediately changes them to a brilliant color. If the brass has become greasy it is first dipped in a strong solution of potash and soda in warm water; this cuts the grease, so that the acid has free power to act.

5.—Rub the surface of the metal with rotten stone and sweet oil, then rub off with a piece of cotton flannel, and polish with soft leather. A solution of oxalic acid rubbed over tarnished brass soon removes the tarnish, rendering the metal bright. The acid must be washed off with water, and the brass rubbed with whiting and soft leather. A mixture of muriatic acid and alum, dissolved in water, imparts a golden color to brass articles that are steeped in it for a few seconds.

6.—First boil your articles in a pan with ordinary washing soda, to remove the old lacquer; then let them stand for a short time in dead nitric acid; then run them through bright dipping nitric

acid. Swill all acid off in clean water, and brighten the relieved parts with a steel burnisher, replace in clean water, and dry out in beech sawdust. Next, place your work on the stove till heated, so that you can with difficulty bear your hand on the articles, and apply pale lacquer with a brush; the work will burn if heated too much or too rapidly.

7.—Put a coat of nitric acid over the part you want cleaned, with a piece of rag; as soon as it turns a light yellow rub it dry, and the brass will present a very clean appearance; if not satisfactory, repeat.

8.—Oxalic acid and whiting, mixed, and applied wet with a brush, and brushed again when dry with a soft plate brush to polish with dry whiting.

9.—Chalk, 10 parts; white bole, 4 parts; magnesium carbonate, 1 part; iron oxide, 1 part.

10.—Oxalic acid, 1 dr.; rotten stone, in powder, 4 oz.; boiling water, 1 oz.; oil of turpentine, ½ dr.; soft soap, ½ oz.; sweet oil, 5 dr. First dissolve the acid in the water, then add the rotten stone and other ingredients.

11.—Oxalic acid, 1 part; iron peroxide, 15 parts; powdered rotton stone, 20 parts; palm oil, 60 parts; petrolatum, 4 parts. See that solids are thoroughly pulverized and sifted, then add, and thoroughly incorporate, the oil and petrolatum.

12.—Starch, 1 part; powdered rotten stone, 12 parts; sweet oil, 2 parts; oxalic acid, 2 parts; water to mix.

13.—To 1 oz. of powdered potassium bichromate add 2 oz. each of sulphuric acid and water. Apply by dipping or rubbing the article to be cleaned, and wash off immediately with water; rub dry, and polish with rotten stone.

14.—Oxalic acid, 3 parts; water, 50 parts; kieselguhr, 7 parts. Dissolve the acid and add the earth. Shake before using.

15.—It would not suffice to pickle brass objects; the brilliancy thus produced would not be durable. To attain a good polish, the surfaces have to be rubbed with very fine tripoli, mixed with olive oil; next rinse with soap water and wipe dry with fine linen.

16.—Brass work that is so dirty from smoke and heat as not to be cleaned with oxalic acid should be thoroughly washed or scrubbed with soda, or potash water, or lye. Then dip in a mixture of equal parts of nitric acid, sulphuric acid and water; or, if it cannot be conveniently dipped, make a swab of a small piece of woolen cloth upon the end of a stick, and rub the solution over the dirty or smoky parts; leave the acid on for a minute, and then wash clean and polish.

17.—Fly Specks, To Remove.—If you cannot wash off the fly specks with soap and warm water on a cloth, there is no way that an amateur can refinish lamp work with any satisfaction. To do this the lamp must be taken apart and the brasswork boiled in caustic soda to remove all oil and varnish; then rinse in hot water and dip in strong nitric acid for a few seconds only, when it will come out clean and bright; then rinse clean in boiling water. Dry in sawdust, brush off, and lacquer with thin shellac varnish. The metal must be warm and perfectly free from grease.

18.—Gun Shells.—For such as have been used, boil in a strong solution of caustic soda, rinse in hot water, then dip in a hot pickle of sulphuric acid, 1 part; water, 4 parts; and rinse in hot water.

19.—Inlaid Work.—Mix tripoli and linseed oil, and dip felt into the preparation. With this, polish. If the wood be rosewood or ebony, polish it with finely powdered elder ashes, or make a polishing paste of rotten stone, a pinch of starch, sweet oil and oxalic acid, mixed with water.

Brass and Copper Polishing

The Wiener Seifensieder-Zeitung publishes the following collection of formulas for copper and brass polishes:

1.—Cream of tartar, 5 parts; alum, 10 parts; sodium chloride, 10 parts; water, 100 parts. The salts are dissolved in the water, and the solution is allowed to stand several days. A white precipitate is formed, from which the liquid is decanted. If turpid, the liquid must be filtered through paper.

2.—Dissolve 10 parts of tartaric acid in 100 parts of water, and mix with 5 to 10 parts of ferric oxide.

3.—Pour 1 part of sulphuric acid carefully into 20 parts of water, stirring with a stick of wood. Dissolve 2 parts of alum in the dilute acid, and add 2 parts of fine potato meal. The meal must be thoroughly rubbed down with the acid liquid, added in small portions at a time, until a homogeneous paste is obtained. This preparation must be kept in bottles closed with paraffined corks.

4.—Oxalic acid, 500 parts; tripoli, or infusorial earth, 150 parts.

5.—Ammonia water, concentrated, 50 parts; water, 100 parts; prepared chalk, 20 parts. Red or yellow aniline dye, as much as desired.

6.—Sal ammoniac, 10 parts, is dissolved in 75 parts of water, and 5 parts of chalk added.

7.—Flowers of sulphur, 10 parts; ground chalk, 10 parts; mix with 100 parts of vinegar.

8.—Alcohol, 80%, 100 parts; olein, 50 parts; tartaric acid, 80 parts; tripoli, 30 parts. Mix the tartaric acid (in powder form) with the alcohol, whereby the acid is partly dissolved. Then add the olein, and finally the tripoli, taking care to mix thoroughly.

9.—Rotton stone, 3 oz.; powdered soap, 1 oz. Apply with a little spirit of turpentine or sweet oil.

10.—Brass, Copper, German Silver, etc., To Polish.—Use Vienna lime, with oil.

Brass.—1.—Rub the metal with rotten stone and sweet oil, then rub off with a piece of cotton flannel, and polish with soft leather. A solution of oxalic acid, rubbed over tarnished brass, soon removes the tarnish, rendering the metal bright. The acid must be washed off with water, and the brass rubbed with whiting and soft leather. A mixture of muriatic acid and alum dissolved in water imparts a golden color to brass articles that are steeped in it for a few seconds.

2.—In polishing old brass work which has been scratched and tarnished by wear, pumice or bath brick should be used with soap and water for scouring off with, and rotten stone, with kerosene oil, for the wet finish, and dry for the final polish. The same method should be used for new brasswork. New work should require, after leaving the lathe and vise tools, but little polishing or grinding, and every good workman should try to avoid using an emery stick or emery cloth, as with proper care in the use of tools a great deal of grinding and polishing can be dispensed with. The polishing of metals varies somewhat according to their character, but the main principle underlying all is the substitution of progressively finer scratches for those left by the material last used, until they become so delicate as to be invisible without the aid of a microscope.

3.—Three parts of oxalic acid are dissolved in 40 parts of hot water; add 100 parts of powdered pumice stone, 2 parts of oil of turpentine, 12 parts of soft soap and 12 parts of a fat oil.

4.—Rotten stone, 7 oz.; powdered oxalic acid, 1 oz. Both are used with a little water.

5.—Soft soap, 2 oz.; rotten stone, 4 oz.; beaten to a paste.

6.—Rotten stone, made into a paste with sweet oil.

7.—Rotten stone, 4 oz.; oxalic acid, in fine powder, 1 oz.; sweet oil, 1½ oz.; turpentine, q. s. to make a paste.

The above are used to clean brasswork, when neither varnished nor lacquered. The first and last are best applied with a little water. Both require friction with soft leather.

8.—Make a paste of equal parts of sulphur and chalk, with sufficient vinegar to reduce it to the proper consistency; apply it to the metal while moist, allow it to dry on, and rub with a chamois skin. For ornaments or engraved work, clean with a brush.

9.—Another process, and one that gives to the brass a very brilliant color, is to make a wash of alum boiled in strong lye, in the proportion of 1 oz. of alum to 1 pt. of lye. Wash the brass with this mixture, and afterward rub with chamois and tripoli.

10.—A weak solution of ammonia in water makes an excellent wash. Apply it with a rag, dry with a piece of chamois, and afterward rub with a piece of chamois and a very small quantity of jewelers' rouge.

11.—Place 2 oz. of sulphuric acid in an earthen vessel and add 1 qt. of cold soft water; after the heat that is generated has passed off add 1 oz. each of tripoli and jewelers' rouge. When well mixed put in a bottle for use.

12.—Brass may be polished without a burnisher by using an exceedingly fine cut file and fine emery cloth.

13.—Small articles to be polished should be shaken by themselves for a short time; then some greasy parings of leather should be put in the barrel with them. After they have been shaken smooth the greasy leather parings are replaced by clean ones, and the shaking is continued as long as necessary.

14.—When the brass is made smooth by turning, or filing with a very fine file, it may be rubbed with a smooth, fine-grained stone, or with charcoal and water. When it is made quite smooth, and free from scratches, it may be polished with rotten stone and oil, alcohol, or spirits of turpentine.

15.—Brasswork can be polished by rubbing the metal with finely powdered tripoli mixed with sweet oil, and applied with a rubber made from a piece of an old hat or felt. Or else a mixture of glycerine, stearine, naphthaline or creosote, mixed with dilute sulphuric acid, can be used.

Bronze and Gilt (See also **Brass and Copper** above)

1.—Clean the surface, first of all, with whiting and water, or crocus powder, until it is polished; then cover with a paste of plumbago and crocus, mixed in the proportions that will produce the desired color. Heat the paste over a small charcoal fire. Perhaps the bronzing has been produced by a corrosive process; if so, try painting a solution of sulphide of potassium over the cleaned metal.

2.—Articles of bronze are best cleaned by the use of a paste made of powdered chicory and water. The paste is spread over the bronze and rubbed well over the surface by means of a stiff brush (an old stiff tooth brush will answer), and then allowed to dry on the article. After drying, rinse off the powder with running water, and dry in the sun. Wiping off with an oiled rag will improve the looks of modern bronzes.

3.—Rub delicate objects with a sponge charged with a mixture of 28 parts of alcohol, 14 parts of water and 4 parts of lavender oil.

4.—Fly Specks.—Lavender oil, 1 dr.; alcohol, 1 oz.; water, 1½ oz. Use a soft sponge, and proceed quickly, with little rubbing.

5.—Gilded Bronze.—a.—Commence by removing the spots of grease and wax with a little potash or soda dissolved in water. Let dry, and apply the following mixture with a rag: Carbonate of soda, 7 parts; whiting, 15 parts; 85° alcohol, 50 parts; water, 125 parts. When this coating is dry pass over it a fine linen cloth or a picee of supple skin. The hollow parts are cleaned with a brush.

b.—After removing the grease spots, as specified above, let dry, and pass over all the damaged parts a pencil dipped in the following mixture: Alum, 2 parts; nitric acid, 65 parts; water, 250 parts. When the gilding becomes bright, wipe, and dry in the sun or near a fire.

c.—Wash in hot water containing a little soda, dry, and pass over the gilding a pencil soaked in a liquid made of 30 parts of nitric acid, 4 parts of aluminum sulphate and 125 parts of pure water. Dry in sawdust.

d.—Immerse the objects in boiling soap water and facilitate the action of the soap by rubbing with a soft brush; put the objects in hot water, brush them carefully, and let them dry in the air; when they are quite dry rub with an old linen cloth or a soft skin the shining parts only, without touching the others.

e.—If greasy, wash carefully in suds; or, better, dip into a hot solution of caustic potash, and then wash in suds with a soft rag, and rinse in running water. If not then clean and bright, dip into the following mixture: Nitric acid, 10 parts; aluminum sulphate, 1 part; water, 40 parts. Mix. Rinse in running water.

f.—Boil in a weak alkali prepared from an infusion of wood ashes. Then clean with a solution composed of equal parts of nitric acid, water and alum.

Copper (See also **Brass**)

1.—Take 1 oz. of oxalic acid, 6 oz. of rotten stone, ½ oz. of gum arabic, all in powder, 1 oz. of sweet oil, and sufficient water to make a paste. Apply a small portion, and rub dry with a flannel or leather.

2.—Use soft soap and rotten stone, made into a stiff paste with water, and dissolved by gently simmering in a water bath. Rub on with a wooden rag, and polish with dry whiting and rotten stone. Finish with a leather and dry whiting.

3.—Copper plates are cleaned by laying them near a fire and pouring on them some turpentine, and then rubbing them with a small, soft brush.

4.—The cleaning of some copper objects with powders or other substances is attended with difficulty on account of their worked and ornamental surfaces. Still, at times, success is complete, by means of acids. If the object is greasy, the grease must first be removed by a hot solution of soda, and then the object immersed in clear water. The bath designed for restoring brilliancy is thus composed: Nitric acid, 2 parts; sal ammoniac, 1 part; or else sal ammoniac, 1 part; nitric acid, 1 part; and water, 1 part. The sal ammoniac is to be dissolved in the water so as to obtain a saturated solution. The object should not be left immersed in the bath more than 2 seconds, and should afterward be rinsed, first in cold water, then in hot, soapy water, and dried with warm sawdust.

5.—Make Armenian bole into a paste with oleic acid.

6.—Rotten stone, 1 part; iron subcarbonate, 3 parts; lard oil, a sufficient quantity.

7.—Iron oxide, 10 parts; pumice stone, 32 parts; oleic acid, a sufficient quantity.

8.—Soap, cut fine, 16 parts; precipitated chalk, 2 parts; jewelers' rouge, 1 part; cream of tartar, 1 part; magnesium carbonate, 1 part; water, a sufficient quantity. Dissolve the soap in the smallest quantity of water that will effect solution over a water bath. Add the other

ingredients to the solution while still hot, stirring all the time to make sure of complete homogeneity. Copper tubing, or other parts of apparatus that cannot be readily cleaned by mechanical means, should be well coated with tin.

Firearms

1.—A good and simple way of cleaning and recoloring the barrels and other metal parts of a double-barrel shotgun which are quite rusty. Take the barrels from the stock and put them in clean cold water free from gritty matters. Attach the brush to the washing rod and get out all adhering powder and residues; next take tow, and wash until the barrels are quite clean. If the parts have rusted, it will be necessary to use a little emery flour. Dry the barrels with clean cotton rags, rubbing until the metal feels warm. Plug the ports and muzzles securely, then cleanse the outside parts with a strong alcoholic solution of caustic potash, aided, if necessary, with a little emery flour and a soft rag. Rinse thoroughly in water, dry thoroughly, warm, and while warm rub over every part with the following preparation: Pure (dry) zinc chloride, 1 oz.; nitrate of antimony, ¼ oz.; olive oil, 2 oz.; well rubbed down into a smooth, uniform paste. After half an hour's exposure, rub off excess of this paste, and polish with clean, soft rags. In warming the metal avoid overheating it so as to injure the temper.

2.—In the volunteer service there are several fluids used, which are composed of either turpentine, naphtha, petroleum, benzine or gasoline, about one-third, or according to fancy, with machine oil. But the instructions to the troops are—a damp rag, flannel or tow, is all that is required to clean the barrel out; if much water is used, it is liable to run into the action. The butt should be raised when washing out. After washing out and drying, an oily rag or flannel to be used. On many occasions the oily material will be found to be efficacious, without the previous use of water.

3.—Easy method of cleaning guns and rifles when loaded. If a muzzle-loader, stop up the nipple or communication hole with a little wax; or, if a breech-loader, insert a cork in the breech rather tightly; next pour some quicksilver into the barrel, and put another cork in the muzzle; then proceed to roll it up and down the barrel, shaking it about for a few minutes. The mercury and the lead will form an amalgam, and leave the barrel as clean and free from lead as the first day it came out of the shop. The same quicksilver can be used repeatedly by straining it through wash leather; for the lead will be left behind in the leather, and the quicksilver will be again fit for use.

4.—If the barrels have become leaded, wet the tow on the rod with spirits of turpentine, as the latter enjoys the property of removing any leading almost equally with quicksilver. Paraffine will also be found useful where neither of the foregoing can be obtained. Never touch the grooves of a rifle with emery, as it will dull their edges, and, consequently, affect the shooting power.

5.—Rusty.—a.—Vaseline oil, 4 parts; French turpentine, 1 part; naphtha, 1 part. It is sufficient to thoroughly saturate the oakum wrapped around the wad hook with this mixture and to wipe the interior of the barrels a few times. Next, rub the barrel stock and system externally with a moistened brush, and wipe the rifle clean with a rag.

b.—A lubricating oil which it is said will clean rust from rifle barrels, and also prevent corrosion by nitro powders, has the following formula: Kerosene (free from acid), 2 oz.; sperm oil, 1 oz.; oil of turpentine, 1 oz.; acetone, 1 oz. Mix in the order given. Oil of citronella or oil of bergamot may be added to disguise the odor.

German Silver, To Polish

Take 1 lb. of peroxide of iron, pure, and put half of it into a wash basin, pouring on water, and keeping it stirred until the basin is nearly full. While the water and crocus are in slow motion, pour off, leaving grit at the bottom. Repeat this a second time, pouring off into another basin. Cleanse out grit, and do the same with the other half. When the second lot is poured off the crocus in the first will have settled to the bottom; pour off the water gently, take out the powder, dry it, and put both, when washed clear of grit, and dried, into a box into which dust cannot get. If the silverwork is very dirty, rub the mixture of powder and oil on with the fingers, and then it will be known if any grit is on the work. If the work is not very black, take a piece of soft chamois leather and rub some dry crocus on, and, when well rubbed, shake out the leather and let the powder fall off that is not used, or rub it off with a brush. Do not put down the leather in the dust.

Iron and Steel

Polishing and Protecting.—a.—Usually, the article to be polished is first rubbed down with emery of gradually increasing

fineness, after which the article is moistened with alcohol or water, and polished with Vienna lime, rouge or tin putty.

b.—Take an ordinary bar of malleable iron, in its usual merchantable state, remove the oxide from its surface by the application of diluted sulphuric acid, after which wash the bar in an alkaline solution, then cover the entire bar with oil or petroleum. The bar is then ready for the chief process. A muffle surface is so prepared that a uniform, or nearly uniform, heat can be maintained within it, and in this furnace the bar is placed. Care must be taken that too great a heat is not imparted to it, for on this depends the success of the operation. When the bar approaches a red heat, and when the redness is just perceptible, it is a certain indication that the proper degree has been attained. The bar is then at once removed and passed through the finishing rolls 5 or 6 times, when it will be found to have a dark, polished, uniform surface, and the appearance of Russian sheet iron.

c.—Steel bits that are tarnished, but not rusty, can be cleaned with rotten stone, common hard soap and a woolen cloth.

d.—Finished Surfaces.—Oil is usually employed for polishing delicate instruments, which tends to soil those using them. Oil may be advantageously replaced by a mixture of 3 parts of glycerine and 1 part of alcohol for large surfaces. When small ones are to be treated, pure glycerine can be used.

2.—Iron.—a.—You cannot keep the bright color of polished iron on the hot parts of an engine without constant attention and wiping with engine oil. Oxalic acid may help the cleaning, but the acid left on the bright surface favors oxidation. For cleaning, use tripoli, rotten stone or pulverized pumice stone, with engine or kerosene oil. Neglected or dirty spots may be removed with a scraper and fine emery paper, and afterward rubbed with oil. Every part of bright work around an engine should be wiped with oil. Moisture immediately discolors a clean, bright surface. Polish the lubricator with rotten stone and oil only, and only when necessary. Too much polishing soon makes it look old from wear.

b.—Bright Polish Like Steel.—Blue vitriol, 1½ oz.; borax, 1½ oz.; prussiate of potash, 1½ oz.; charcoal, 1½ oz.; salt, ¾ pt. Pulverize and dissolve in 1½ qt. of hot water; add 1½ gal. of linseed oil; mix well. Bring the iron or steel to the proper heat, and cool in this solution.

c.—Brilliant Luster, To Give.—Pulverized arsenious acid, 7½ dr.; elutriated bloodstone, 7½ oz.; antimony trichloride (butter of antimony), 3¾ oz. Pour over these materials 5 pt. of 90% alcohol. Digest at a gentle heat, shaking frequently. When iron is polished with this fluid it precipitates upon it a thin film of antimony and arsenic, which protects the iron from oxidation, and also gives it a fine appearance.

3.—Machinery, Tools, etc.—a.—Two or three cents' worth of paraffine, chipped fine, are added to 1 l. of pertoleum in a stoppered bottle, and during 2 or 3 days, from time to time, shaken up until the paraffine is dissolved. To apply it, the mixture is well shaken, spread upon the metal to be cleaned, by means of a woolen rag or brush, and on the following day rubbed off with a dry woolen rag.

b.—In a corked bottle, mix 20 parts of petroleum with 1 part of paraffine; apply the mixture by means of a rag or brush, and rub well the next morning with dry wool.

c.—Oil of turpentine, 5 parts; stearine, 25 parts; polishing red, 25 parts; animal charcoal, 25 parts; stir into spirit, and shake well until a homogeneous liquid mass has been obtained. This is applied with a brush, and the spirit allowed to evaporate. The surface is then rubbed with a mixture of 25 parts of red and 45 parts of animal charcoal.

4.—Steel.—Glaze Wheels for Finishing.—For hollow finishing, the following wheels are required: A mahogany wheel for rough glazing, a mahogany wheel for smooth glazing, a mahogany wheel for flat finishing: A buff wheel for rough, a buff wheel for smooth, a buff wheel for finishing. Lastly, a polisher. To make the glaze wheels: Get the spindles, and point them on each end; then get a block of beech, and wedge it on the steel at one end with iron wedges, and turn it for the pulley for the band to run on. Take two pieces of flat mahogany, and glue and screw them together, so that the grain of one piece crosses the other, to prevent warping. Let it get thoroughly dry, and wedge it on the spindle and turn it true. The lead wheel is made the same way, but wider, and has a groove turned in the edge. The wheel is put into sand, and a ring of lead run around the edge; it is then turned true. To make the buff wheels, proceed as with the glaze, but to save expense, pine or deal wood will do as well as mahogany, only leave it about double the width of the glaze, which is about ½ in. wide by 12 or 14 in. across. The buff wheels are

(Metal Cleaning)

covered with glue, and then the leather is tacked on with tacks driven in about half way, so that they may be easily drawn out again. The leather is then turned true. The polisher is made the same way, but the size of the polisher must be a little less than any of the other wheels, say about 1 in. The buff wheels are dressed by laying on a fine thin coat of clear glue and rolling them around—No. 1 in superfine corn emery, No. 2 in smooth emery, No. 3 by making a cake of equal parts of mutton suet, beeswax and washed emery; then it is held on the wheel while it is going around. The glaze wheels are dressed while using, by mixing a little of the emery with oil, and putting it on the wheel with a stick or the finger. The leather of the polisher is not covered with glue, but dressed with a mixture of crocus and water, not oil. Care must be taken to keep each wheel and substance to themselves; the work must be carefully wiped after each operation, and cleanliness must be studied above all things in using the polisher, as the slightest grease getting on it stops the polishing.

a.—Polishing.—(1) Use bell-metal polishers for arbors, having first brought up the surface with oilstone dust and oil and soft steel polishers; for flat pieces, use a piece of glass for the oilstone dust, a bell-metal block for the sharp red stuff, and a white metal block for the fine red stuff. The polishing stuff must be well mixed up, and kept very clean; the polishers and blocks must be filed to clean off the old stuff, and then rubbed over with soft bread; put only a little red stuff on the block, and keep working it until it is quite dry; the piece will then leave the block quite clean; use bread to clean off the surplus red stuff before using the brush. If the piece is scratched, put on some more red stuff, which must not be too wet, and try again.

(2) The polish on flat steel pieces in fine watchwork is produced with oilstone dust, burnt Turkey stone, and a steel polisher, soft steel, bell metal, and sharp stuff, grain tin and glossing stuff. The metals are squared with a file, and vary in shape according to the work in hand.

Metals (See also **Brass and Copper; Iron and Steel; Nickel; Rust; Silver**; in this chaper)

1.—The preparation of polishes, simple as it seems, is an art, and, like every other, requires a certain amount of practical experience as well as a knowledge of the materials entering into the composition of the polishing mixture used, and of their preparation for use. To attain a high and uniform grade of polish, the materials must be reduced to a very fine and uniform powder. One single grain of the material larger or sharper than the rest will produce scratches that interfere with the finish given the metal. The substances in general use are prepared chalk, rotten stone, tripoli and emery. For the finest work, jewelers' rouge is employed. Substances like emery are most useful for the harder metals; they scratch too much to be used to any extent on gold or silver. All should be run through a fine sieve before being used.

2.—Cloths, Polishing.—These are undyed velveteen, in the stage of manufacture known as "dressed off." They may be improved by soaking in a solution of ammonia or a saturated solution of hyposulphite of soda, then dried. Polishing tissue was thin paper, saturated with ammonia solution and dried; it is now obsolete.

3.—Jewelers' Polishing Bar.—Refined tallow, 80 lb.; sesquioxide of iron, 16 lb.; oxalic acid, 1 lb. Powder the acid, mix with the sesquioxide, and mold with the tallow into bars, like soap. The sesquioxide must be quite free from grit, or it may scratch valuable work. It may be prepared by calcining equal amounts of oxalic acid and iron sulphate in a crucible for about 15 minutes, with a good draught.

4.—Jewelers' Rouge.—To make sure of your jewelers' rouge being free from dust and grit, prepare it fresh, as follows: Make a solution of iron sulphate (copperas), and another of oxalic acid. Add the latter to the former, as long as it throws down a precipitate. Filter off the liquid, and wash the residue on the filter with repeated charges of water, and dry. When dry, place in a suitable container, and heat gently. It soon ignites, and burns until only an impalpable powder is left. This is the polishing material. The infusorial earth must be freed from sand, grit, etc., and reduced, by grinding, to a condition similar to that of the iron peroxide. The rotten stone and acid must also be powdered. If care and attention be given to these details, you can scarcely fail to get good results.

5.—Liquid Polish.—Sometimes it is desirable to have a liquid polish for metals. Properly speaking there can be no such thing, as the polishing process depends, as we have already pointed out, on the attrition of fine particles of some substance a little harder than the metal. The powders used can be, and frequently are,

employed in a moist condition, and they may be suspended in water by shaking. A mixture of whiting and ammonia water is frequently used for cleaning metals, the ammonia acting as a solvent of some kinds of dirt. It is best, however, to remove grease, etc., before beginning the polishing process, and the effects of strong alkalies on the hands are not pleasant. It is true that the acids, by their chemical action, remove rust and dirt from metallic surfaces without the aid of any of these hard, fine powders, but they generally remove also a portion of the metals themselves each time they are applied. A weak solution in water of any of the strong mineral acids, or even of citric or oxalic acid, might be found useful in a number of instances, but could not be recommended for general use.

a.—Prepared chalk, 2 parts; water of ammonia, 2 parts; water, sufficient to make 8 parts. The ammonia saponifies the grease usually present. It must be pointed out that the alkali present makes the preparation somewhat undesirable to handle, as it will affect the skin if allowed too free contact.

b.—Malt vinegar, 4 gal.; lemon juice, 1 gal.; paraffine oil, 1 gal.; kieselguhr, 7 lb.; powdered bath brick, 3 lb.; oil of lemon, 2 oz. Well mix.

c.—Kieselguhr, 56 lb.; paraffine oil, 3 gal.; alcohol, 1½ gal.; camphorated spirit, ½ gal.; turpentine oil, ½ gal.; liquid ammonia fort., 3 pt. Pour the ammonia into the oil, alcohol and turpentine, add the camphorated spirit, and mix with the kieselguhr. To prevent setting, keep well agitated during filling. The color may be turned red by using a little sesquioxide of iron and less kieselguhr. Apply with a cloth, and, when dry, use another clean cloth, or a brush.

d.—Precipitated chalk, 30 parts; ammonia water, 30 parts; alcohol, 45 parts; water, 200 parts. For polishing silver and other metals.

e.—Dried sodium carbonate, 1 part; soap, 4 parts; flour of emery, 25 parts; water, enough to make a paste.

f.—Prepared chalk, 8 oz.; oil of turpentine, 2 oz.; alcohol, 1 oz.; water of ammonia, 2 dr.

g.—Peroxide of iron (jewelers' rouge) 20 parts; rotten stone, 20 parts; infusorial earth, 20 parts; oxalic acid, 1 part; palm oil, sufficient; vaseline, sufficient; oil of mirbane, sufficient to perfume. Pulverize, and mix, so proportioning the palm oil and vaseline that you have a liquid sufficiently "thick" to hold the powders in suspension.

h.—Naphtha.—(1) A mixture of equal parts of sperm oil, paraffine oil and naphtha is said to make a good cleaner for metals, and is a lubricant as well.

(2) Venice tripoli, 1 lb.; Spanish whiting, 1 lb.; powdered pumice, 8 oz.; kerosene, 3 oz.; crude oleic acid, 3 oz.; crude petroleum jelly to make a paste. Naphtha might be used in place of the kerosene. When naphtha or benzine is used there is always more or less danger from fire. They evaporate rapidly on exposure to the air, and unless the polish containing them is used at once, or is kept in a tightly closed container, they will probably be entirely lost.

i.—Star Metal Polish.—Powdered tripoli, 3 oz.; tartaric acid, 1 dr.; powdered pumice, ½ oz.; gasoline, 14 fl.oz. Shake well, and apply with a woolen cloth until the dirt is removed; then polish with chamois.

j.—Tripoli, 9 kgm.; infusorial earth, 9 kgm.; Japanese wax, 5 kgm.; olein, 12 kgm.; benzine, 90 kgm.

k.—Fulmenol.—Chalk, 100 kgm.; olein, 64 kgm.; ammonia water, 38 kgm.; alcohol, denatured, 49 kgm.; benzine, 49 kgm.

l.—Rotten stone, 16 av.oz.; paraffine, 8 av.oz.; kerosene (coal oil), 16 fl.oz.; oil of mirbane, enough to perfume. Melt the paraffine, incorporate the rotten stone, add the kerosene and the oil of mirbane when cold.

m.—Oxalic acid, ½ av.oz.; rotten stone, 10 av.oz.; kerosene (coal oil), 30 fl.oz.; paraffine, 2 av.oz. Pulverize the oxalic acid, and mix it with the rotten stone; melt the paraffine, add to it the kerosene, and incorporate the powder; when cool, add oil of mirbane or lavender, to perfume.

6.—Pastes and Pomades.—a.—Melt 5 lb. of lard or yellow vaseline, and mix with 1 lb. of fine rouge.

b.—Melt together 2 lb. of palm oil and 2 lb. of vaseline, and stir in 1 lb. of rouge, ½ lb. of tripoli and 1 oz. of oxalic acid.

c.—Buff Color.—Petroleum Jelly, 42 lb.; refined paraffine wax, 14 lb.; powdered bath brick, 14 lb.; powdered pipeclay, 14 lb.; powdered pumice, 2 lb.; yellow ocher, 2 lb.; oleic acid, 1 lb.; oil of cassia, 3 oz. Melt the wax and jelly, stir in the others and grind as before.

d.—Putz Pomades.—The Journal der Goldschmiedekunste gives the first 3 formulæ following for polishing pomades:

(1) Anhydrous sodium carbonate, 5 parts; tallow soap, 20 parts; levigated emery, 100 parts; water, 100 parts. Mix, put on the water bath, and heat, under constant agitation, until a smooth, homogeneous paste has been obtained.

(2) Jewelers' rouge, 1 part; petrolatum, 1 part; oil of mirbane, q. s. to perfume. Mix intimately.

(3) Oil of turpentine, 1 part; levigated emery, finest, 1 part; jewelers' rouge, 2 parts; petrolatum, 2 parts; oil of mirbane, q. s. Rub up together to a homogeneous pomade.

(4) Rotten stone, 1 part; iron subcarbonate, 3 parts; lard oil, enough.

(5) Iron oxide, 10 parts; pumice stone, 32 parts; oleic acid, enough.

(6) Soap, cut fine, 16 parts; precipitated chalk, 2 parts; jewelers' rouge, 1 part; cream of tartar, 1 part; water, enough. Dissolve the soap in the smallest quantity of water over a water bath; add the other ingredients to the solution while still hot, stirring all the time, to make sure of complete homogeneity; pour the mass into a box with shallow sides, and afterward cut into cubes.

(7) Petrolatum, 42 parts; refined paraffine, 14 parts; powdered bath brick, 14 parts; powdered pipeclay, 14 parts; powdered pumice, 2 parts; oleic acid, 1 part.

(8) Dried sodium carbonate, 5 parts; soap, 20 parts; levigated emery, 100 parts; water, 100 parts. Mix, put on a water bath, and heat, under constant agitation, until a smooth, homogeneous paste has been obtained.

(9) Emery flour, 50 parts; jewelers' rouge, 50 parts; mutton suet, 40 parts; oleic acid, 40 parts. Melt the suet and oleic acid together over a water bath, and when thoroughly mixed remove from the fire; when cooled, but still soft, add the powders, and rub until they are evenly distributed throughout the mass.

7.—Powders.—a.—Kieselguhr, 80 parts; tin oxide, 30 parts; pipeclay, 30 parts; tartaric acid, 3 parts.

b.—Kieselguhr, 28 parts; pipeclay, 10 parts; sodium hyposulphite, 3 parts; ferric oxide, 2 parts.

c.—Chalk, 10 av.oz.; white bole, 4 av.oz.; lead carbonate, 5 av.oz.; magnesium carbonate, 1 av.oz.; iron oxide, 1 av.oz. This mixture is best adapted to brass and copper.

d.—Calcined magnesia, 8 av.oz.; jewelers' rouge, 8 av.oz. This mixture is recommended for polishing gold; it should be used dry.

e.—Magnesium carbonate, 4 av.oz.; chalk, 4 av.oz.; jewelers' rouge, 7 av. oz.

f.—Palm oil, 16 av.oz.; petrolatum, 16 av.oz.; jewelers' rouge, 8 av.oz.; tripoli, 7 av.oz.; oxalic acid, 160 gr.

g.—Hard Metals.—Science, Arts and Nature gives the following: Infusorial earth, 80 parts; tin oxide, 30 parts; pipeclay, 30 parts; tartaric acid, 3 parts. Powder and mix.

h.—Kieselguhr, 28 parts; pipeclay, 10 parts; sodium hyposulphite, 3 parts; ferric oxide, 2 parts.

i.—Kieselguhr, 42 lb.; putty powder, 14 lb.; pipeclay, 14 lb.; tartaric acid, 1½ lb. Powder the acid, mix well with the others. This is styled "free from recury, poisonous mineral acids, alkalies, or grit." It may be tinted with 12 oz. of oxide of iron, if desired.

8.—Preserving the Polish on Bright Surfaces.—Take 2¼ oz. of rosin and from 15 to 20 oz. of lard; melt slowly together, stirring until cool. The mixture is used when semi-fluid. It may be thinned by coal oil or benzine. Put on a bright surface, even thinly, it will preserve the polish, and it can be readily rubbed off.

9.—Soaps.—a.—Liquid curd soap, 20 to 25 lb., intimately mixed with about 30 lb. of fine chalk and ½ lb. of Venetian red.

b.—Liquid cocoanut-oil soap, 26 lb., mixed with 12 lb. of tripoli and 1 lb. each of alum, tartaric acid and white lead.

c.—Melted cocoanut oil, 25 lb., saponified with 12 lb. of soda lye of 38 to 40° B., after which 3 lb. of rouge, 3 lb. of water and 2 oz. of ammonia are crutched in.

d.—Powdered pipeclay, 112 lb.; tallow soap, 16 lb.; tartaric acid, 1¼ lb. Grind until pasty; afterward press into blocks by the machine.

e.—Levigated flint, 60 lb.; whiting, 52 lb.; tallow, 20 lb.; caustic soda, 5 lb.; water, 2 gal. Dissolve the soda in the water and add to the tallow; when saponified, stir in the others, pressing as before.

Nickel

1.—To clean nickelplated objects, dip them for a second or two in a 2% solution of sulphuric acid, rinse in running water, and finally with a mixture, in equal parts, of distilled water and alcohol. Dry in sawdust.

2.—Polish.—a.—Ordinary rouge is used by nickelplaters as a polish.

b.—Another preparation, said to be an excellent one, is made by mixing ½ oz. of quicksilver and 2 oz. of chalk. To use, add a small quantity of alcohol, and polish with a chamois skin. These polishes do not restore the plating, however, and if the nickeling be worn off, the only thing to do is to have the article replated.

c.—Use chalk mixed with tallow.

d.—Equal parts of precipitated iron carbonate and prepared chalk, or take quicksilver with chalk, ½ oz., and prepared chalk, 2 oz., and mix them. When used, add a small quantity of alcohol, and rub with chamois leather.

e.—Rouge with a little flesh lard or lard oil, on a wash leather or piece of buckskin. Rub the bright parts, using as little of the rouge and oil as possible; wipe off with a clean rag slightly oiled. Repeat the wiping every day, and polishing as often as necessary.

3.—Rust, Protection.—In putting away a bicycle for the winter, every part should be thoroughly cleaned from dirt, the running parts duly oiled, and the bright parts wiped with a mixture of vaseline and paraffine (2 parts of vaseline to ½ part of paraffine), to which add ½ pt. of finely ground quicklime by heating and stirring; apply warm, by wiping all the nickel parts, and wrapping them in paper which has been coated on one side by the mixture, very thin, which will keep off rust and dampness. The japanned parts and saddle should also be nicely covered with wrapping paper to keep off dust, which injures the japan by long contact.

4.—Rust, Removal.—First cover the objects with grease, and in 3 or 4 days rub them with a rag soaked in ammonia. This will dissolve the rust without attacking the nickel. If the rust resists this treatment, apply a little chlorhydric acid, and immeditely afterward rub with a cloth, so that the nickeling may not be affected. Then wash, dry well, and polish.

Pewter Articles

The cleansing of articles of this metal is accomplished with hot lye of wood ashes and fine sand. Pour the hot lye upon the tin, throw on sand, and rub with a hard woolen rag, hat felt, or whisk, until all particles of dirt have been dissolved. To polish pewter plates, it is well to have the turner make similar wooden forms fitting the plates, and to rub them clean this way. Next they are rinsed off with clean water and placed on a table with a clean linen cover, on which they are left to dry without being touched otherwise spots will appear. This scouring is not necessary so often if the pewter is rubbed off with wheat bran after use and cleaned perfectly. New pewter is polished with a paste of whiting and brandy, of which a little is used, rubbing the dishes with it until the mass becomes dry.

Rust

Metals.—1.—Drawing Instruments, Removing Rust from.—a.—Use fine emery paper and crocus cloth.

b.—Mix 10 parts of tin putty, 8 parts of prepared buck's horn and 25 parts of 90% aclohol to a paste. Cleanse the articles with this, and finally rub with soft blotting paper.

2.—Gun Barrels, Grease for Anointing, to Prevent Rust.—Make an ointment of corrosive sublimate and lard. It is said that this will protect gun barrels from rust on the seashore.

3.—Iron and Steel, Rust Preventives.—a.—Caoutchouc oil is said to have proved efficient in preventing rust, and to have been adopted by the German army. It only requires to be spread with a piece of flannel, in a very thin layer, over the metallic surface and allowed to dry up. Such a coating will afford security against all atmospheric influences and will not show any cracks under the microscope after a year's standing. To remove it, the article has simply to be treated with caoutchouc oil again, and washed after 12 to 24 hours.

b.—A solution of india-rubber in benzine has been used for years as a coating for steel, iron and lead, and has been found a simple means of keeping them from oxidizing. It can be easily applied with a brush, and is as easily rubbed off. It should be made about the consistency of cream.

c.—All steel articles can be perfectly preserved from rust by putting a lump of freshly burnt lime in the drawer or case in which they are kept. If the things are to be moved (as a gun in its case, for instance), put the lime in a muslin bag. This is especially valuable for specimens of iron when fractured, for in a moderately dry place the lime will not want renewing for many years, as it is capable of absorbing a large quantity of moisture. Articles in use should be placed in a box nearly filled with thoroughly pulverized slaked lime. Before using them rub well with a woolen cloth.

d.—The following mixture forms an excellent brown coating for protecting iron and steel from rust: Dissolve 2 parts of crystallized iron chloride, 2 parts of antimony chloride and 1 part of tannin in 4 parts of water, and apply with a sponge or rag, and let dry. Then another coat of the paint is applied, and again another, if necessary, until the color becomes as dark as desired. When dry, it is washed with water, allowed to dry again, and the surface polished with boiled linseed

oil. The antimony chloride must be as nearly neutral as possible.

e.—Put about 1 qt. of fresh slaked lime, ½ lb. of washing soda and ½ lb. of soft soap in a bucket; add sufficient water to cover the articles; put in the tools as soon as possible after use, and wipe them up next morning, or let them remain until wanted.

f.—Soft soap, with about half its weight of pearlash; 1 oz. of the mixture in about 1 gal. of boiling water. This is in every-day use in most engineers' shops in the drip cans used for turning long articles bright in wrought iron and steel. The work, though constantly moist, does not rust, and bright nuts are immersed in it for days till wanted, and retain their polish.

g.—Melt slowly together 6 or 8 oz. of lard to 1 oz. of rosin, stirring till cool; when it is semi-fluid it is ready for use, If too thick, it may be further let down by coal oil or benzine. Rubbed on bright surfaces, ever so thinly, it preserves the polish effectually, and may be readily rubbed off.

h.—To protect metals from oxidation—polished iron or steel, for instance—the requisite is to exclude air and moisture from the actual metallic surface; wherefore, polished tools are usually kept in wrappings of oiled cloth and brown paper, and, thus protected, they will preserve a spotless face for an unlimited time. When these metals come to be, of necessity, exposed, in being converted to use, it is necessary to protect them by means of some permanent dressing, and boiled linseed oil, which forms a lasting film or covering as it dries on, is one of the best preservatives, if not the best. But in order to give it body it should be thickened by the addition of some pigment, and the very best—because the most congenial—of pigment is the ground oxide of the same metal; or, in plain words, rusted iron reduced to an impalpable powder, for the dressing of iron or steel, which thus forms the pigment of red oxide paint.

i.—Slake a piece of quicklime with just water enough to cause it to crumble, in a covered pot, and while hot add tallow to it and work into a paste, and use this to cover over bright work; it can be easily wiped off.

j.—Olmstead's varnish is made by melting 2 oz. of rosin in 1 lb. of fresh, sweet lard, melting the rosin first and then adding the lard, and mixing thoroughly. This is applied to the metal, which should be warm, if possible, and perfectly cleaned; it is afterward rubbed off. This has been well proved and tested for many years, and is particularly well suited for planished and Russian iron surfaces, which a slight rust is apt to injure very seriously.

k.—Use ferroline or white zapon lacquer.

l.—Mix whiting and linseed oil together to form a paste. Put a coat on the iron. It is easily removed, and will prevent rusting.

m.—Thick lubricating petroleum, or solid paraffine, applied to the slightly warmed iron, is one of the best preservatives; in some cases a transparent varnish of copal or shellac is preferable. The main point is to clean the iron properly before the application, from all traces of rust, by means of brushing and a mineral acid, to wash it well, and to neutralize all remaining traces of acid with potash lye, or with lime or some other alkali; then clean and dry thoroughly, and apply your oil, paraffine or varnish.

n.—Boiled linseed oil will keep polished tools from rusting if it is allowed to dry on them. Common sperm oil will prevent them from rusting for a short period. A coat of copal varnish is frequently applied to polished tools exposed to the weather. Woolen materials are the best for wrappers for metals.

o.—Iron and steel goods of all descriptions are kept free from rust by the following: Dissolve ½ oz. of camphor in 1 lb. of hog's lard, take off the scum, and mix as much black lead as will give the mixture an iron color. Iron and steel, and machinery of all kinds, rubbed over with this mixture, and left with it on for 24 hours, and then rubbed with a linen cloth, will keep clean for months. If the machinery is for exportation, it should be kept thickly coated with this during the voyage.

p.—Antimony chloride, 9 parts; crystallized iron chloride, 9 parts; tannin, 4½ parts, in 18 parts of water. Apply with a sponge or rag, let it dry, apply again, if necessary. This mixture forms a brown coating on the article. When dry, wash with water; let it dry, then polish with boiling linseed oil.

q.—A compound of grease and zinc filings is found to be an excellent preventative against rust for iron bolts inserted in wood. It is used to line the bolt hole.

r.—A correspondent sends us the following suggestions: "I have tried many things, but found nothing better than boiled linseed oil to protect instruments and tools (files, saws, guns, etc.) from rusting. It even works best with a kettle used for heating water for bathing. Wipe the metal with a cloth dipped in

the oil, and let it dry, which will require only a few minutes. If it is unnecessary to have the metal bright and shining, you need not scour it before the application of the oil; this will combine with the rust, and form a firm, durable coating."

s.—Rub over with a mixture of tallow or lard and thick white-lead paint.

t.—To keep iron goods of any kind, and especially those parts of machines which are made of steel or iron, from rusting, take ½ oz. of powdered camphor, and melt it before the fire in 1 lb. of good lard. To give it a dark color, add as much fine black lead as is necessary to produce the desired effect. Clean the ironwork, and smear it over with this preparation. After this it should be allowed to remain untouched for 24 hours, when the grease should be removed by wiping the iron work with a soft cloth.

u.—Vaseline is an excellent preservative. Buy by the can, and apply with a brush.

4.—Iron, Protection from Rust.—a.—Otto Hering, of Berlin, has lately patented a method for producing basic oils to protect iron from rust. The oil is made to contain in solution certain basic substances. Either the oil (fatty or mineral) may be saturated with ammonia gas at the ordinary temperature, or organic bases can be dissolved in it. In practice, a combination of these two plans is advisable, the ammonia gas being put into the oil after the organic bases. An advantage claimed for this new rust protector is that it contains no moisture, and is mixed with bodies able to check any tendency to rust formation at the outset.

b.—Barff's Process.—A patented process employed for the protection of the surfaces of iron from rust, effected by artificially coating them with a film of magnetic oxide. The iron is first heated to redness, and steam passed over it. The iron decomposes the steam, liberating oxygen, which latter immediately attacks the iron, forming magnetic or black oxide, Fe_3O_4.

c.—Bright Iron Articles.—The medium in question is produced from the following substances: Zinc white, 30 kgm.; lampblack, 2 kgm.; tallow, 7 kgm.; vaseline, 1 kgm.; olive oil, 3 kgm.; varnish 1 l. Boil together ¼ hour and add ½ l. of benzine and ¼ l. of turpentine, stirring the mass carefully and boiling for some time. The finished pastelike substance can be readily removed with a rag without the use of solvents.

d.—Underground Iron.—Cotton-seed or linseed oils, 1 lb.; coal tar, 1 lb.; sulphur, 1 lb.; heat separately; mix thoroughly, and heat to 300° F. for about 1 hour, at the end of which time it becomes pasty. Heat the metal to which it is applied.

5.—Iron, Removal of Rust.—a.—A simple and effective way of cleaning rusted iron articles, no matter how badly they are rusted, consists in attaching a piece of ordinary zinc to the articles, and then letting them lie in water to which a little sulphuric acid is added. They should be left immersed several days, or a week, until the rust has entirely disappeared, the time depending on how deeply they are rusted. If there is much rust, a little sulphuric acid should be added occasionally. The essential part of the process is that the zinc must be in good electrical contact with the iron. A good way is to twist an iron wire tightly around the object, and connect this with the zinc. Besides the simplicty of this process, it has the great advantage that the iron itself is not attacked in the least so long as the zinc is in good electrical contact with it. Domestic Engineering says that when there is only a little rust, a galvanized-iron wire wrapped around the object will take the place of the zinc, provided the acid is not too strong. The articles will come out a dark gray or black color, and should then be washed thoroughly and oiled. The method is specially applicable to objects with sharp corners or edges, or to files and other articles on which buffing wheels ought not to be used. The rusted iron and the zinc make a short-circuited battery, the action of which reduces the rust back to iron, this action continuing as long as any rust is left.

b.—Iron articles thickly coated with rust may be cleaned by allowing them to remain in a nearly saturated solution of chloride of tin from 12 to 14 hours.

c.—Rust remover: Ground pumice, 30 grams; oleic acid, 20 grams; tallow 2 grams; paraffine, 4 grams. The last three ingredients are melted together and the powdered pumice is slowly stirred in.

6.—Nickelplated Articles, To Remove Rust from.—Cover the stains with oil or grease for a few days, and then remove the rust by rubbing with a little ammonia. If this does not remove the rust, try very dilute hydrochloric acid. When dry, polish with tripoli or whiting.

7.—Rust Prevention in General.—a.—Melt together 125 parts of lard and 20 parts of camphor, to which a little graphite is added. After thorough cleaning, the mass is rubbed on and allowed to remain 24 hours.

b.—A mixture of petrolatum and kerosene oil is said to be an excellent application for protecting the surface of the metal.

c.—For polished metal use the following: Rosin, 35 parts; talc, in powder, 500 parts; lard, 250 parts; yellow wax, 130 parts; olive oil, 130 parts; oil of turpentine, 130 parts. Mix the rosin, lard, wax and oil, and melt at a low temperature; when melted, stir in the talc, and after removing from the fire add the turpentine, with constant stirring.

d.—Camphor, ½ oz.; dissolve in melted lard, 1 lb.; take off the scum, and mix in as much black lead as will give it an iron color; clean machinery, and smear with compound; after 24 hours remove with a soft linen cloth.

8.—Rust Removal in General.—a.—Cover the metal with sweet oil, well rubbed in, and allow to stand for 48 hours; smear with oil, applied freely with a feather or piece of cotton wool, after rubbing the steel; then rub with unslaked lime, reduced to as fine a powder as possible.

b.—Immerse the article to be cleaned for a few minutes until all dirt and rust is taken off, in a strong solution of potassium cyanide, say about ½ oz. in a wineglassful of water; take out, and clean it with a toothbrush, with some paste composed of potassium cyanide, Castile soap, whiting and water, mixed into a paste of about the consistency of thick cream.

9.—Steel, Removal of Rust.—a.—The following solution according to the National Druggist, may be applied by means of a brush, after having removed any grease by rubbing with a clean, dry cloth: Stannic chloride, 100 grams, are dissolved in 1 l. of water; this solution is next added to one containing 2 grams of tartaric acid dissolved in 1 l. of water, and, finally, adding 20 c.cm. of indigo solution diluted with 2 l. of water. After allowing the solution to act upon the stain for a few seconds it is rubbed clean, first with a moist cloth, later with a dry cloth. To restore the polish, use is made of silver sand and jewelers' rouge.

b.—Immerse the article to be cleaned for a few minutes until all dirt and rust are taken off, in a strong solution of cyanide of potassium, say about ½ oz. in a wineglassful of water; take out, and clean it with a tooth brush, with some paste composed of cyannide of potassium, Castile soap, whiting and water; these last are mixed in a paste about the consistency of thick cream.

c.—To remove rust from small hollow castings, dip in dilute sulphuric acid (1 part of commercial acid to 10 parts of water). Wash in hot lime water, and dry in a tumbler in dry sawdust.

d.—Immerse the articles in kerosene oil; allow them to remain for some time. This will loosen the rust so it will come off easily.

e.—To remove rust from steel, cover the metal with sweet oil, well rubbed in; 48 hours afterward rub with finely pulverized unslaked lime.

f.—Cover the rusted part with oil or fat, let it remain 3 hours, then wipe off with a cloth; take 2 dr. of caustic potash and 4 oz. of opodeldoc; rub on the mixture, and let it remain 10 minutes; rub off with a dry cloth. Or, cover the rusted parts with sweet oil, well rubbed in, and next day cover with finely powdered unslaked lime; polish with this until the rust disappears. Or, take ½ oz. of emery powder, 1 oz. of soft soap, mixed, and well rub in.

g.—Whiting, by weight, 9 parts; oil soap, by weight, 6 parts; cyanide of potassium, by weight, 5 parts; water, by weight, 60 parts. Dissolve the soap in the water, over the fire, and add the cyanide; then, little by little, add the whiting. If the compound is too thick, which may be due either to the whiting or the soap employed, add a little water until a paste is made which can be run into an iron or wooden mold. This will remove rust from steel and give it a good polish.

h.—Rosin, 35 parts; powdered talc, 500 parts; lard, 250 parts; yellow wax, 130 parts; olive oil, 130 parts; oil of turpentine, 130 parts. Mix the rosin, lard, wax and oil, and melt at a low temperature. When melted, stir in the talc, and, after removing from the fire, add the turpentine, with constant stirring.

i.—Rust Paper for Fine Steel.—Wash some pumice in water, powder it fine, and mix linseed-oil varnish with the powder. Apply several coatings of this mixture with a brush, to good, firm paper, and after the paper has been dried in the air pass it between smoothing rollers. The following cleaning powder is also recommended: Mix 16 parts by weight of tin putty with 8 parts of prepared hartshorn, and rub the mixture to a paste with 32 parts of alcohol. The mixture can then be used for cleaning steel articles. Very rusty steel and iron articles should first be washed with hydrochloric acid, diluted with an equal quantity of water, and afterward with pure water, then dried, coated with oil, left for a few

days, and finally cleaned with the cleaning powder already described. Finely powdered emery, with a little olive oil, can also be recommended.

10.—Steel Instruments, Small, To Keep from Rusting.—a.—Clean frequently; after using, clean with dry chamois leather and wipe off with an oiled rag.

b.—For this purpose the Lancet confidently recommends a mixture of equal parts of carbolic acid and olive oil, smeared over the surface of the instruments. This plan is much used by medical officers in the navy, and is found to preserve the polish and brightness of the steel, however moist and warm the climate may be.

11.—Steel Wire, To Protect from Rust.—Try the following: Dissolve ½ oz. of camphor in 2 oz. of 90% alcohol, and mix this with 2 pt. of fine sperm oil. Allow the wire to remain in contact with this mixture, heated to 180° F., for half an hour; then rub off excess with a soft cotton cloth.

12.—Stoves, To Prevent from Rusting.—Apply kerosene with a cloth. This will prevent stoves from rusting during the summer. Also an excellent material to apply to all iron tools used about a farm.

13.—Tools, To Keep from Rusting.—a.—Put ¼ lb. of soft soap in a pail and add 1 pt. of freshly slaked lime; sufficient water to cover the articles. Place the tools in this mixture as soon as possible after they are used. Wipe them the next morning.

b.—Apparatus for Coating Laboratory Tools.—Metallic Tools and other articles, particularly those consisting of iron or steel, which are used in laboratories or other workshops where acid vapors are of frequent occurrence, may be protected from rust with a black shining coat, which resists acids, and is but little affected even by a low red heat, in the following manner: Have a sheet-iron box large enough to hold all the tools, etc., to be coated, and provided with a false bottom of wire netting. Underneath this is placed a layer of crushed coal (blacksmith's coal) about 1 cm. deep; then place the tools, which must be entirely free from rust, clean and polished, upon the wire net. The box is then covered and set on a strong fire, which causes the coal to give off tarry constituents, and the heat continued until the bottom of the box is at red heat. When all evolution of gas has ceased the box is allowed to become cold, and the tools are taken out, and will be found covered with a beautiful glossy coat. Tongs, shears, pincers, etc., so coated, keep in good condition for months, even in places where the air is constantly mixed with acid vapors.

Silver

1.—In cleaning silver plate, or any polished metallic surface, it is very essential to keep the polishing material, as well as the rubbing cloths, chamois, etc., in a close box, where they cannot be contaminated with dust. One single grain of sand may produce a scratch that hours of faithful labor cannot obliterate. When this happens the injured article must be sent to the jeweler to have the scratch burnished out.

2.—Silver articles discolored by sulphureted hydrogen may be cleaned by rubbing them with a boiling saturated solution of borax. Another good preparation is a solution of caustic potash with some bits of metallic zinc.

3.—Ammonium carbonate, 1 oz.; water, 4 oz.; Paris white, 16 oz.; mix well, and apply by means of soft leather.

4.—Rouge (very fine) and prepared chalk, equal parts; use dry.

5.—Whiting (fine), 2 parts; white oxide of tine, 1 part; calcined hartshorn, 1 part.

6.—A fresh concentrated solution of hyposulphite of soda will dissolve at once the coat of sulphide of silver, which is the cause of the blackness produced by mustard, eggs, etc., or anything containing sulphur.

7.—Egg Stains.—Rub with common salt. A pinch taken between the thumb and finger, and rubbed on the spot with the end of the finger, will usually remove the darkest egg stain.

Zinc

1.—To clean zinc, mix 1 part of sulphuric acid with 12 parts of water; dip the zinc into it for a few seconds, then rub with a cloth.

2.—Zinc articles, if small, can be cleaned by being pickled in hydrochloric acid with water added, till the articles are nicely cleaned, in about 3 minutes, without being too strongly attacked, then washed and dried. Large articles like refrigerators are cleaned by being rubbed with a swab dipped in raw spirits, then washed with water, and finished with whiting.

CHAPTER IV.

COLORING OF METALS

CLEANING, DIPPING AND PICKLING

Articles may be cleansed from dirt by washing with water and brushing with white sand, pumice, whiting, etc. Grease and fatty matter, as well as lacquer on old work, may be best removed by boiling in a hot solution of caustic potash or soda, contained in a cast-iron pot. After boiling for some time they should be removed, and, if not perfectly clean, it may be necessary to scour with fine sand, swill in water, and again suspend in the solution.

Aluminum

Articles of aluminum are cleaned in a very dilute solution of potash, when the surface assumes a bright appearance; wash well with warm water and dry with a warm cloth. Aluminum alloys are treated like copper alloys.

Copper and Its Alloys

Copper, brass, bronze, etc., become oxidized in ordinary moist air, and, in consequence of the simultaneous presence of carbonic acid, may become gradually converted into carbonates. In fact, the brownish-black to bluish-green deposit often seen on copper, brass and bronze goods is a mixture of oxide and carbonate of copper mixed with oxygen compounds of zinc or tin, respectively, when the copper is present as an alloy of these metals.

Dipping in Nitric Acid, Common Salt and Soot.—Brass, and similar articles, after cleaning in pickle, are rinsed in water, well shaken and drained, then dipped in a bath consisting of 100 parts of nitric acid, 1 part of common salt and 1 part of calcined soot. This mixture attacks the metal with great energy, and, therefore, it should only remain in it a few seconds. The volume of acid should be 20 times that of the articles immersed in it, to prevent undue heating and too rapid weakening of the acid. When removed, the articles should be quickly rinsed in water to prevent the production of nitrous fumes. They then present a fine luster, varying from red to golden yellow and greenish yellow, according to the composition of the alloy.

Dead Dipping.—To the above ingredients add a mixture of the following if a dead surface is desired: Nitric acid, 1 lb.; strong sulphuric acid, ½ lb.; common salt, 5 gr.; zinc sulphate, 20 gr. The longer the articles remain in this dip the deader will be the surface. They are then thoroughly swilled and dried as quickly as possible. Or previous to swilling with water they may be momentarily dipped in the bright dipping liquid.

Another liquid for dead dipping may be made of 1 volume of a concentrated solution of potassium bichromate and 2 volumes of a concentrated hydrochloric acid. The articles should be left in this solution for some hours, then well swilled in several wash waters. If, however, they are left exposed to the air for some time without lacquering or further treatment, they become coated with a film of oxide. Dead-dipped articles, while waiting to be bronzed or lacquered, may be kept from oxidizing by immersing in clean water to which half its volume of alcohol has been added. In the case of copper alloys, such as brass, the surface color will depend not only on the original composition of the alloy, but also on the length of time it has been exposed to the action of the acid. The zinc is oxidized more rapidly than the copper, so that the effect of dipping in nitric acid or other oxidizing liquid is to increase the relative quantity of copper on the surface, and to give to the alloy a richer appearance and a deeper color. When it is desired to clean very small articles, and not to appreciably alter the composition, they may be dipped in a solution of 5 parts of potassium cyanide dissolved in 95 parts of water.

Iron and Steel

For cleaning iron articles generally, a cold mixture of about 20 measures of water and 1 measure of sulphuric acid is frequently used; but a better liquid is

composed of 1 gal. of water, 1 lb. of sulphuric acid, with 1 or 2 oz. of zinc dissolved in it; to this is added ½ lb. of nitric acid. This mixture leaves the iron quite bright, whereas dilute sulphuric acid alone leaves it black, or of a different appearance at the edges. It should be scoured with sharp sand and brushed with a steel scratch brush.

Lead, Tin, and Their Alloys

These metals are cleaned to remove dirt and grease, as with other metals, by means of a caustic alkali solution, and brushing with sand, etc.

ALUMINUM

Aluminum, To Blacken

White arsenic, 1 oz.; sulphate of iron, 1 oz.; hydrochloric acid, 12 oz.; water, 12 oz. When the arsenic and iron are dissolved by the acid add the water. The aluminum to be blackened should be well cleaned with fine emery powder, and washed, before immersing in the blackening solution. When the deposit of black is deep enough, dry off with fine sawdust and lacquer.

Coppering

1.—Sulphate of copper, 30 parts; cream of tartar, 30 parts; soda, 25 parts; water, 1,000 parts. It suffices to plunge the articles to be coppered in this bath, but they have to be well cleaned previously.

2.—By means of a battery: Phosphate of sodium, 50 parts; cyanide of potassium, 50 parts; cyanide of copper, 50 parts; distilled water, 1,000 parts.

BRASS

A method is with chloride of platinum. For this purpose they are first heated to redness, and then dipped in a weak solution of sulphuric acid. Afterward they are immersed in dilute nitric acid, thoroughly washed in water, and dried in sawdust. To effect a uniformity in the color they are plunged in a bath consisting of 2 parts of nitric acid and 1 part of rain water, where they are suffered to remain for several minutes. Should the color not be free from spots and patches, the operations must be repeated until the desired effect is produced.

Black

A very good black color can be obtained on brass by a solution of copper nitrate, 50 parts; water, 100 parts. If the work is too large for immersion, it is heated, and the solution is applied by means of a paint brush, when the heating is continued until the surface is dry. It is then gently rubbed with a linen pad and brushed with or immersed in a solution of potassium sulphide, 10 parts; water, 100 parts; hydrochloric acid, 5 parts. Immersion of the work in the liquid produces much better results, and, after draining off the superfluous liquid it is heated on a hot plate or over a clean fire till dry. We have obtained more uniform results by using a solution about three times more dilute than the preceding solution of copper nitrate, viz.: Copper nitrate, 100 parts; water, 600 parts. The heating process must not be continued longer than is necessary to convert the whole of the green salt which forms on drying into the black copper oxide. A good black can thus be produced on brass in this way without recourse to the second pickling in potassium sulphide, but this second pickling is probably advantageous in fixing the color.

Black Bronze for Brass.—Dip the article, bright, in nitric acid, rinse the acid off with clean water, and place it in the following mixture until it turns black: Hydrochloric acid, 12 lb.; sulphate of iron, 1 lb.; pure white arsenic, 1 lb. It is then taken out, rinsed in clean water, dried in sawdust, polished with blacklead, and then lacquered with green lacquer.

The dead black on optical instruments is produced by dipping in a solution of chloride of platinum. To make this, take 2 parts of hydrochloric acid, 1 part of nitric acid, mix in a glass bottle, and put in as much platinum foil as the acid will dissolve when placed in warm sand bath; or, to hasten the solution, heat to nearly the boiling point of the acids; ½ oz. of nitric acid and 1 oz. of hydrochloric acid will absorb about 30 gr. of platinum, but in order to neutralize the acid it is better to have a surplus of platinum. Dip the article or brush in the chloride.

Blue-black.—Copper carbonate, 7 oz., is dissolved in 1½ qt. of strong ammonia. A precipitate is formed, and the solution is diluted with 1 qt. of water.

Optical Instruments and Other Brass Work.—For dead black for inside of tubes, use alcoholic shellac varnish and lampblack, equal parts by weight, and thin with enough alcohol to make it flow freely with the brush.

Bronzing Brass by Simple Immersion

Water.	Nitrate of iron.	Perchl'de of iron.	Permur'te of iron.	Nitrate of copper.	Tersulph. of arsenic.	Muriate of arsenic.	Pot. sol'n sulphur.	Pearlash solution.	Cyanide of potass.	Ferrocy'de potass.	Sulphocy'de potass.	Hyposulph. of soda.	Nitric acid.	Oxalic acid.	Color.
pt.	dr.	dr.	pt.	oz.	gr.	oz.	dr.	dr.	oz.	pt.	dr.	dr.	dr.	oz.	
1	5														Brown and every shade to black.
1		5													Brown and every shade to black.
1	16											16			Brown and every shade to red.
1												16	1		Brown and every shade to red.
1				1										1	Brownish red.
										1			3		Brownish red.
1									1				4		Dark brown.
1					30			6							Yellow to red.
1							1								Orange.
2			1												Olive green.
1		5									2				Slate.
1												20			Blue.
1						1									Steel gray.
1			2			10									Black.

In preparation of No. 5, liquid must be brought to a boil, and cooled. In using No. 13, the heat of the liquid must not be under 180°. No. 6 is slow in action. The action of the others is, for the most part, immediate.—[English pint, 20 oz.—Ed.]

Dulling Brass

Take 1 part, by weight, of iron rust, 1 part of white arsenic, and 12 parts of hydrochloric acid; mix. Clean the brass thoroughly, and apply with a brush until the color desired is obtained; then oil well, dry, and lacquer.

Green

1.—Sulphate of copper, 120 gr.; hydrochlorate of ammonia, 30 gr.; water 1 qt.

2.—Dissolve 2 oz. of nitrate of iron and 2 oz. of hyposulphite of soda in 1 pt. of water. Immerse the articles in the bronze till of the required tint, as almost any shade from brown to red can be obtained; then well wash with water, dry, and brush. One part of perchloride of iron and 2 parts of water, mixed together, and the brass immersed in the liquid, gives a pale or deep olive green, according to the time of immersion. If nitric acid is saturated with copper, and the brass dipped in the liquid and then heated, it assumes a dark green. If well brushed, it may be lacquered with pale gold lacquer, or else polished with oil.

3.—The repeated applications of alternate washes of dilute acetic acid and exposure to the fumes of ammonia, will give a very antique-looking green bronze; but a quick mode of producing a similar appearance is often desirable. To this end the articles may be immersed in a solution of 1 part of perchloride of iron in 2 parts of water. The tone assumed darkens with the length of the immersion.

Patina

1.—This beautiful color was originally produced by articles being exposed for a long time to the action of the atmosphere. The green color is largely imitated by either of the following methods: Copper carbonate is triturated with sandarac varnish. This affords the cheapest and poorest imitation, and is largely used in painting the little iron castings which are so largely sold in Rome for souvenirs.

2.—Copper, 30 grams; concentrated nitric acid, 60 grams; acetic acid, 6%, 600 grams; ammonium chloride, 11 grams; ammonia water, 20 grams. The copper is dissolved in the nitric acid, and as soon as solution is effected the other ingredients are added. The solution must be allowed to stand several days before using. The objects to be coated are either dipped into the solution for a moment or the solution is applied to the surface by means of a brush. They are then allowed to dry, and are finally covered with a thin coat of linseed oil.

Steel Blue

1.—Dissolve 3 dr. of antimony sulphide and 4 oz. of calcined soda in 1½ pt. of water. To this add 5½ dr. of kermes. Filter, and mix this solution with 5½ dr. of tartar, 11 dr. of sodium hyposulphite and 1½ pt. of water. If polished sheet brass is placed in the warm mixture, it will assume a beautiful steel-blue color.

2.—The brass, laid in a leaden vessel containing hydrochloric acid and a little arsenic acid, assumes iridescent tints, and may be removed when the desired shade of blue is obtained.

BRONZING

Antique Bronzes.—In order to give new bronze castings the appearance and patina of old bronze, various compositions are employed, of which the following are the principal ones:

1.—Vinegar, 1 l.; sal ammoniac, 8 grams; potassium bioxalate, 1 gram.

2.—Water, 120 grams; copper sulphate solution, 80 grams (d = 1.46); sal ammoniac, 10 grams; cream of tartar, 3 grams; sea salt, 60 grams.

3.—Vert Antique.—a.— Vinegar, 1 l.; copper sulphate, 16 grams; sea salt, 32 grams; sal ammoniac, 32 grams; mountain green (Sanders green), 70 grams; chrome yellow, 30 grams; ammonia, 32 grams.

b.—Vinegar, 1 l.; copper sulphate, 16 grams; sea salt, 32 grams; sal ammoniac, 32 grams; mountain green, 70 grams; ammonia, 32 grams.

c.—To obtain darker vert antique, add a little plumbago to the preceding mixtures.

4.—Vert à l'eau.—Vinegar, 1 l.; sal ammoniac, 50 grams; ammonia, 50 grams; mountain green, 70 grams; chrome yellow, 30 grams.

For bronzing immerse the object in any of the foregoing mixtures, or cover it rapidly with a soft brush. The object will turn more or less green according to the length of time it is immersed or has been under the action of the fluid. The excess of the fluid is removed by means of a long-haired brush, and after that the article is allowed to dry for 24 hours. A second or even third coating may be applied, if necessary, in order to obtain darker shades. The bronze is finished by an energetic brushing with wax or olive oil or a mixture of both.

COPPER

To Color Copper and Nickelplated Objects.—The Journal des Applications Electriques says that 11 different colors may be communicated to well-cleaned copper and 8 to nickelplated objects, by means of the following bath: Acetate of lead, 300 gr.; hyposulphite of soda, 600 gr.; water, 1 qt. After the salts are dissolved the solution is heated to ebullition and the metal is afterward immersed therein. At first a gray color is obtained, and this, on the immersion being continued, passes to violet, and successively to maroon, red, etc., and finally to blue, which is the last color. As the substances that enter into the composition of the solution cost but a few cents, the process is a cheap one. It is especially applicable in the manufacture of buttons.

Blacking

1.—To give a copper article a black covering clean it with emery paper, heat gently in a Bunsen or a spirit flame, immerse for 10 seconds in a solution of copper filings in dilute nitric acid, and heat again.

2.—To color copper black, immerse the object, previously well cleaned, in the following and let remain for from 30 to 45 minutes, and afterward wash well: Antimony chloride, 15 parts; alcohol, 125 parts; hydrochloric acid, sufficient to dissolve. Mix. The less of the acid that is used the better the result. This process deposits a coating of antimony.

3.—Plunge the object in nitric acid, remove, and heat to a dull red. Deposits a coating of copper oxide.

Bluing

1.—Dip the article in a solution of 2 oz. of liver of sulphur and 2 oz. of chlorate of soda in 1,000 oz. of water.

2.—Dip the article in a solution of ferrocyanide of potassium very strongly acidulated with hydrochloric acid.

Bronzing

1.—A dilute solution of ammonium sulphide, used cold, yields very beautiful effects, as shown by the following results: This solution works very well for copper, but it is not suitable for brass. The solution works well either hot or cold, strong or dilute. The colors depend more upon the manipulation of the process than upon either temperature or density. Colors may be obtained ranging from a neutral crimson through brown and steel gray to black. This solution may be used for bronzing work which is too large to immerse in the solution, by moistening it with a sponge or cloth, then allowing the articles to stand exposed to the air till they are dry, when they may be scratch-brushed and the moistening repeated if the color is not

deep enough, or the bronzing not uniformly distributed. When the right tint is attained the articles should be thoroughly washed, first with warm water, then with cold water, and finally dried out in sawdust and brushed with a wax brush.

2.—Having thoroughly cleaned and polished the surface of the specimen, with a brush apply the common crocus powder, previously made into a paste with water. When dry place it in an iron ladle, or on a common fire shovel, over a clear fire, for about 1 minute, and when sufficiently cool polish with a plate brush. By this process a bronze similar to that on tea urns is produced.

3.—By substituting finely powdered plumbago for crocus powder in the above process a beautiful deep color is produced.

4.—Rub the metal with a solution of potassium sulphide (liver of sulphur, old name), then dry. This produces the appearance of antique bronze very exactly.

5.—Dissolve 2 oz. of verdigris and 1 oz. of sal ammoniac in 1 pt. of vinegar, and dilute the mixture with water until it tastes but slightly metallic, when it must be boiled for a few minutes and filtered for use. Copper medals, etc., previously thoroughly cleaned from grease and dirt, are to be steeped in the liquor at the boiling point, until the desired effect is produced. Care must be taken not to keep them in the solution too long. When taken out they should be carefully washed in hot water and well dried.

Bronzing Fluids for Copper by Simple Immersion.

Water.	Nitrate of iron.	Sulphate of copper.	Sulphide of antimony.	Sulphur.	Muriate of arsenic.	Pearlash.	Sulphocyanide of potassium.	Hyposulphite of soda.	Hydrochloric acid.	Color.
pt.	dr.	oz.	dr.	dr.	dr.	oz.	dr.	oz.	dr.	
1	5	..	..	..	..	..	..	..	..	Brown and every shade to black.
1	5	..	..	..	..	..	2	..	..	Dark brown drab.
1	..	1	..	..	..	..	..	1	2	Dark brown drab.
1	..	..	2	..	..	1	..	..	..	Bright red.
1	..	..	..	1	..	1	..	..	..	Red and every shade to black.
1	..	..	..	..	1	..	..	..	..	Steel gray at 180°.

Browning of Copper

1.—The following solution has been recommended for producing a reddish-brown color, which becomes paler on heating: Dissolve 1 part of copper acetate in 16 parts of water; then add sufficient ammonia to give a deep blue solution, and add 2 parts of potassium sulphide, 3 parts of ammonia, and 10 parts of water. Copper acetate, 60 gr.; water, 2 fl. oz.; ammonia, till the solution is blue; potassium sulphide, 120 gr.; ammonia, 3 fl. dr.; water, 1¼ fl. oz. This solution gave precisely the same results as with potassium sulphide and water, so that the other constituents appear to be useless. The reaction on copper is instantaneous, but brass is simply tarnished.

2.—A very beautiful and pleasing color of a light brown shade may be quickly produced by a mixture of 1 part copper sulphate, 1 part zinc chloride and 1 part water. The above forms a paste which is applied to the article and allowed to dry on it. It is then well washed with water, when a uniform color is obtained. This would be one of the most valuable colors if it were permanent, but, unfortunately, it is changed by the action of light to a dark green, almost black. This change also occurs when the bronze is coated with a film of transparent lacquer, and although we have tried several methods for preventing the change, no suitable remedy has yet been discovered.

Green

Sodium chloride 37 parts; ammonia water, 75 parts; ammonium chloride, 37 parts; strong wine vinegar, 5,000 parts. Mix, and dissolve. Apply to the object to be treated with a camel's-hair pencil. Repeat the operation until the desired shade of green is reached.

Bluish Green.—1.—After using the first formula (for green) pencil over with

the following solution: Ammonium chloride, 40 parts; ammonium carbonate, 120 parts; water, 1,000 parts. Mix, and dissolve.

2.—Corrosive sublimate, 25 parts; potassium nitrate, 86 parts; borax, 56 parts; zinc oxide, 113 parts; copper acetate, 220 to 225 parts. Mix, and heat together on the surface of the object under treatment.

Bronze Green Dip.—Wine vinegar, 2 qt.; verditer green, 2 oz.; sal ammoniac, 2 oz.; alum, 1 oz.; salt, 2 oz.; alum, ½ oz.; French berries, 8 oz.; boil the ingredients together.

Olive Green.—Cover with a solution of iron and arsenic in hydrochloric acid. Polish with lead minium, warm, and cover with the following varnish: Gum gutta, 1 part; yellow ocher, 1 part; alcoholic varnish, 1 part. Mix.

Yellow-Green.—1.—Oxalic acid, 5 parts; ammonium chloride, 10 parts; acetic acid, 30% dilution, 500 parts. Mix, and dissolve. Use as above indicated.

2.—The following will produce the same result: Potassium oxalate, acid, 4 parts; ammonium chloride, 16 to 17 parts; vinegar containing 6% of acetic acid, 1,000 parts. Mix, and dissolve. Use as before.

Oxidizing

1.—Copper and Brass.—Immerse the articles in a solution of 2 oz. of nitrate of iron and 2 oz. of hyposulphite of soda to 1 pt. of water, until the desired shade of oxidation is acquired; then wash, dry, and brush.

2.—Platinum Solution.—Dissolve sufficient platinum in aqua regia, and carefully evaporate the resulting solution (chloride of platinum) to dryness. The dried mass may then be dissolved in alcohol, ether, or water, according to the effect which it is desired to produce, a slightly different effect being produced by each of the solutions. Apply the solution of platinum with a camel's-hair brush, and repeat the operation as often as may be necessary to increase the depth of tone. A single application is frequently sufficient. The ethereal or alcoholic solution of platinum must be kept in a well stoppered bottle, and in a cool place. The aqueous solution of platinum should be applied hot.

Red

1.—To redden copper, hang it for from a few minutes to an hour, according to the shade wanted, in a 5 to 10% solution of ferrocyanide of potassium in water. By adding a little hydrochloric acid to the solution the color given to the copper may be made to assume a purple shade. On removing the copper dry it in the air, or in fine sawdust; rinse, and polish with a brush or chamois leather, after drying it again.

2.—Royal Copper Finish.—The copper coloring is termed royal copper from its intense red color. It is produced by dipping in a solution of 2 dr. of sulphide of antimony, 1 oz. of pearlash to 1 pt. of water, or by boiling the copper articles for 15 minutes in a strong solution of tartar and water.

Silver

Nitrate of silver, 60 gr.; common salt, 40 gr.; cream of tartar, 7 dr. This will be ready for application when mixed and moistened with a little water.

GOLD

This operation consists of imparting a color to gold articles after every other process has been completed. Its object is to give to alloyed gold all the appearance of fine gold itself, by dissolving out the base metal from the surface of the articles and leaving a facing of gold of a deep, rich color. Two distinct modes of coloring are adopted by jewelers, termed, respectively, dry coloring and wet coloring. The latter is most frequently practised, as the former cannot well be applied to gold inferior to 18 carats.

Dry Coloring

This term is applied to the coloring process when no liquids are used as constituents of the mixture. The ingredients used are: Potassium nitrate, 8 oz.; common salt, 4 oz.; alum, 3 oz. These substances are ground to a fine powder, well mixed, and placed in a previously heated blacklead color pot, of the same dimensions as that described for use in wet coloring, but the same pot must not be employed for dry coloring as has been used for the wet process. It is well to get the pot nearly red hot before placing the color in it. The mixture must then be constantly stirred with an iron rod. It will first boil up as a greenish liquid, then solidify, and afterward boil up a second time, and become thoroughly fused, having a brownish-yellow color. At this stage the work, which has been previously annealed and dipped in dilute aquafortis, is dipped in the color, being suspended on a silver or platinum wire, the latter being preferred, and kept in motion for about a minute and a half, then immersed in boiling water containing a little aquafortis. The immersion

and swilling are again repeated, when the articles possess a beautiful color. They are then washed in hot water containing a little potash, and finally dried in warm boxwood sawdust. In dry coloring, the work should be as highly polished as possible previous to the coloring, for the brighter it is the better will be the final color. The time given above is only intended as a general guide, as some work will color much quicker than others, and the time can only be arrived at by experience. The following mixtures have been recommended for coloring:

Process.—1.—Potassium nitrate, 8 oz.; common salt, 4 oz.; alum, 4 oz.

2.—Sal ammoniac, 4 oz.; potassium nitrate, 4 oz.; borax, 4 oz.

Wet Coloring

The ingredients of the mixture employed in this process have a powerfully solvent action on the base metal with which the gold is alloyed, and a weaker action on the gold itself, so that the article loses weight in direct ratio to the length of time it is submitted to the coloring process, and this loss is greater as the gold is lower in quality. Gee states that the coloring is hastened, and the loss in weight reduced to a minimum, by using old coloring liquid, and he assumes that the dissolved gold is, to some extent, deposited again on the article, because the loss in weight of some common qualities of gold was found to be very little, and the amount of gold recovered from the spent coloring liquid very small indeed. This statement is in accord with the well-known fact that in any liquid in which a metal, say copper, is electropositive to the metal in solution, say gold, the latter is deposited on the former. The following has been supplied by an experienced Birmingham jeweler, which he has found to be effective: Potassium nitrate, 12 oz.; common salt, 6 oz.; hydrochloric acid, 3 oz. The nitrate and salt are pounded to a fine powder, and placed in a previously warmed plumbago crucible about 8 by 7 in., then stirred with a wooden spoon for a minute or two. The acid is then added, with about 1 oz. of boiling water, and the mass constantly stirred until it boils up to the top of the pot. The work, which has been previously cleansed in hot potash or soda solution, is then suspended in the coloring liquid by means of a silver or platinum wire for about one minute, then well swilled in boiling water. A little more water is added to the color pot, and when the liquid boils up the work is again immersed for another minute, and swilled in boiling water as before. This operation of dipping and swilling is repeated several times, the coloring liquid being weakened by adding water before each immersion, until the desired appearance is attained. The work is finally well washed in hot water and dried in boxwood sawdust. The whole process takes 5 to 7 minutes. The colored work is next scratch-brushed, on a lathe, with a revolving brush made of very fine brass wire, and having stale beer dropping on it. If the coloring has been properly conducted, a beautiful rich and dead color is produced.

Process.—1.—

Potassium nitrate....	8	14	15	14
Common salt........	4	7	7	7
Alum	4	7	7	..
Hydrochloric acid.....	..	2	1	5
Water in each case....	..	..	..	..

2.—The following is a useful mixture for removing tarnish from colored gold articles which have been kept in stock for some time: Bicarbonate of soda, 2 oz.; chloride of lime, 1 oz.; common salt, 1 oz.; water, 16 oz. Well mix the above ingredients, and apply with a soft brush.

IRON AND STEEL

Blacking

Blue Black.—Clean the object thoroughly, remove every trace of grease, then cover with the following: Copper sulphate, 8 parts; nitric acid, 15 parts; alcohol, 30 parts; water, 125 parts. Mix, and dissolve. Let dry on, and when quite dry rub with a woolen cloth.

Brilliant Black.—Boil together: Sulphur, 1 part; oil of turpentine, 10 parts. While boiling, spread in a very light coating, by means of a pencil, over the surface, and heat in the flame of an alcohol lamp until black.

Gun Metal.—For blacking gun barrels: Solution of nitric acid, 2 oz.; tincture of iron, 4 oz.; alcohol, 3 oz.; sweet spirits of niter, 1 oz.; blue vitriol, 1 oz.; rain water, 1½ pt. Scour the barrel smooth; remove all grease with lime, then coat freely with the mixture with a piece of sponge, but not so as to run about the barrel. Let stand in a cool place for about 10 hours, then remove to a warm room, and let stand till dry, when the rust will fly off and not be sticky or streaky. The barrels are not dry, and must stand until quite dry, or the result will be a red barrel. The scratching must be done with lard, then boil for about 10 minutes; take out, and wipe inside and out; let stand till cool, then scratch to remove the dead rust; wipe with a clean rag, then coat

with the mixture lightly; let it stand till dry. Scratch, boil, etc., as in first coat, for 6 coats, when the barrels may be finished by oiling.

Bluing

Gun Metal.—1.—Revolver.—Sometimes the steel is heated to a light gray color, allowed to cool, and reheated until blue. (a) Get as high a polish as possible on the part which you want to blue. (b) Get an iron box made (thin sheet iron). If for the chamber only, say about 6 in. square; no need for rivets; just doubled together. (c) Pound up some wood charcoal; fill your box with it; put the box on a fire (any fire); stir up the charcoal now and again, till you find it is partly ignited. Now put your chamber into the box of partly ignited charcoal; put it in about midway, so as to have as much heat at the bottom as at top and sides. (d) Have handy a handful of dry powdered lime and a piece of tow or cotton waste; you will want a small pair of tongs, or other means of lifting your article out of the box. When you put the article in the box place it again on the fire. Now you must pay attention to it; lift it out about every 10 minutes, and don't stand looking at it, but at once rub it with the tow dipped in the lime. As quickly as possible put back into the charcoal. Don't let your charcoal get too hot; when you see it getting very hot lift the box off the fire and stand it in any convenient spot; replace on fire again, if necessary. Now, the following is important: Your chamber, in a short time, gets of a purple color, then bright blue. It is very tempting to leave off at this bright blue. Don't. This first blue is no good; at least no good where the article has to be rubbed and cleaned. Continue. The bright blue will depart, leaving your chamber nearly as before you put it in the box. Don't forget every 7 or 10 minutes to take out the article and rub it with the tow and dry lime. It must not be kept long in the air. Presently you should obtain a rich dark blue. Finally, when blued, let it cool, then oil (any oil).

2.—Gun Barrels.—To stain, dissolve 4½ oz. of hyposulphite of soda in 1 qt. of water, also 1¼ oz. of acetate of lead in 1 qt. of water. Mix the two solutions and bring to a boil in a porcelain dish or stone pot. Clean the gun barrel free from grease, oil or varnish, warm the barrel, and smear with the hot solution, using a piece of sponge tied to a stick. When color develops, wash, and wipe dry; finish with boiled linseed oil.

Without Heat.—1.—Clean every part carefully, and apply nitric acid, 1 part, diluted with 10 parts of water, until a blue film is produced on the surface. Then wash with warm water, dry, and wipe with linseed oil.

2.—Solution of potassium ferrocyanide and water, 1:200; solution of ferric chloride, 1:200. Mix the two solutions, and dip.

3.—Antimony trichloride, 25 parts; nitric acid, fuming, 25 parts; hydrochloric acid, 50 parts. Apply with a rag, and rub, until the proper color is obtained, with a piece of green oak.

Steel.—Try the following: Scour the steel with a small quantity of a strong aqueous solution of soda, rinse in water, warm, and brush over with a solution of ¼ oz. of chloride of iron dissolved in 5 oz. of water, and let it dry; then apply in the same manner a solution of 1-5 of an ounce of pyrogallic acid in 1 oz. of water; dry, and brush. Does not wear well without lacquering. The blue oxide is sometimes imitated by using a thin alcoholic shellac varnish, colored with aniline blue or Prussian blue.

Bronzing

Lay the object for a moment in a solution of iron perchloride and copper sulphate, with a little added nitric acid. Remove, and dry at a temperature of about 30° C. (85° F.). Finally, suspend in a close box containing a vessel of boiling alcohol, and leave for 20 minutes, keeping the alcohol boiling all the time. Scratch off with a scratch brush. Repeat the operation several times, or until the desired tint is obtained.

Cast Iron.—The Maschinenbauer describes the following process for imparting to common cast iron all the rich glow of bronze, without covering it with a metal or an alloy. Thoroughly cleanse the surface, and rub it down smooth; apply evenly a coat of vegetable oil, say sweet or olive oil, and heat the iron object, being careful that the temperature does not rise high enough to burn the oil. At the moment of decomposition of the oil the cast iron will absorb oxygen, and this forms upon the surface a brown oxide skin or film, which takes a fast hold, and is so hard that it will admit of a high polish, thus bestowing upon the iron a most striking resemblance to bronze.

Browning

Dissolve in 4 parts of water 2 parts of crystallized iron chloride, 2 parts of antimony chloride and 1 part of gallic acid, and apply the solution with a

sponge or cloth to the article, and dry it in the air. Repeat this any number of times, according to the depth of color which it is desired to produce. Wash with water, and dry, and finally rub the articles over with boiled linseed oil. The metal thus receives a brown tint, and resists moisture. The antimony chloride should be as little acid as possible.

Guns.—1.—The following recipe for browning is from the U. S. Ordnance Manual: Alcohol, 1½ oz.; tincture of iron, 1½ oz.; corrosive sublimate, 1½ oz.; sweet spirits of niter, 1½ oz.; blue vitriol, 1 oz.; nitric acid, ¾ oz. Mix, and dissolve in 1 qt. of warm water, and keep in a glass jar. Clean the barrel well with caustic soda water to remove grease or oil. Then clean the surface of all stains and marks by emery paper or cloth, so as to produce an even bright surface for the acid to act upon, and one without finger marks. Stop the bore and vent with wooden plugs. Then apply the mixture to every part with a sponge or rag, and expose to the air for 24 hours, when the loose rust should be rubbed off with a steel scratch brush. Use the mixture and a scratch brush twice, and more, if necessary, and finally wash in boiling water, dry quickly, and wipe with linseed oil, or varnish with shellac.

2.—Sulphate of copper, ½ av.oz.; corrosive chloride of mercury, 1 av.oz.; tincture of chloride of iron, 4 fl.oz.; alcohol., 4 fl.oz.; strong nitric acid, ½ fl.oz. Mix, and apply to the metal, which must be perfectly clean from all dirt or grease, with a sponge or rag; allow to remain 24 hours, so as to get thoroughly dry, then burnish with a hard brush. To obtain the desired shade of color, repeat the application and burnishing as often as is necessary, and then lacquer the metal with a thin, clear lacquer.

Coppering

Sulphate of copper, 1½ lb.; dissolve, and add 1 fl. oz. of sulphuric acid.

Frosting Steel

Clean and polish the metal, flow it quickly with dilute nitric acid, and when the proper point is reached wash well in running water.

Gilding

Polished steel may be beautifully gilded by means of the ethereal solution of gold. Dissolve pure gold in aqua regia, evaporate gently to dryness, so as to drive off the superfluous acid, redissolve in water, and add 3 times its bulk of sulphuric ether. Allow to stand for 24 hours in a stoppered bottle, and the ethereal solution of gold will float on top. Polished steel, dipped in this, is at once beautifully gilded, and by tracing patterns on the surface of the metal with any kind of varnish beautiful devices in plain metal and gilt will be produced. For other metals the electro process is best.

NICKEL

1.—The following solution gives nickel a rich, velvety black color: Water, 3 l. 785 grams; nickel-ammonium sulphate, 34.02 grams; potassium sulphocyanide, 85.05 grams; copper carbonate, 56.70 grams. The same effect is produced by a solution of arsenic trioxide in ammonium carbonate.

2.—Nickel, as well as copper, can be blackened by brushing with an aqueous solution of platinic chloride.

SILVER

Blackening

1.—Plunge into a solution of an alkaline sulphide. Remove, and rub with a brush dipped in powdered cream of tartar.

2.—Rub the object with a solution of silver nitrate.

Browning

To give silver a deep brown color, treat it with a solution of sal ammoniac and copper sulphate, in equal parts, in vinegar.

Frosting and Whitening of Silver Goods, Pickle for

1.—Sulphuric acid, 1½ dr.; water, 6 oz. Heat, and immerse the silver until frosted as desired. Wash well, dry with a soft linen cloth or in fine sawdust. For whitening only, use less acid.

2.—Polished Silver.—Make a solution of ½ oz. of cyanide of potassium in ¼ pt. of water. Apply to the silver with a brush. Hold the silver with pliers made of lancewood or boxwood. Very poisonous.

Gilding

1.—Dissolve equal parts, by weight, of bichloride of mercury (corrosive sublimate) and chloride of ammonium sal ammoniac) in nitric acid; now add some grain gold to the mixture, and evaporate the liquid to half its bulk; apply while hot to the surface of the silver article.

2.—A rich gold tint may be imparted to silver articles by plunging them into dilute sulphuric acid saturated with iron rust.

3.—Water Gilding.—Pour strong vine-

gar on copper flakes; add alum and salt in equal quantities; set on a fire, and when the vinegar has boiled until it becomes ¼ part its original quantity throw into it the metal you design to gild, and it will assume a copper color. Continue boiling, and it will change into a fine gold color.

Oxidizing

1.—Add four or five thousandths of ammonium sulphide or potassium sulphide to water at a temperature of 160 to 180° F. When the articles are dipped into this solution an iridescent coating of silver sulphide is produced, which, after a few seconds, turns blue black if allowed to remain in the liquid. Remove, rinse, scratch-brush, and burnish when desired.

2.—There are two distinct shades in use, one produced by a chloride, which has a brownish tint, and the other by sulphur, which has a bluish-black tint. To produce the former it is only necessary to wash the article with a solution of sal ammoniac (ammonium chloride).

3.—A much more beautiful tint may be obtained by employing a solution composed of equal parts of copper sulphate and ammonium chloride in vinegar (or dilute acetic acid). The fine black tint may be produced by a slightly warm solution of sodium or potassium sulphide.

4.—Bromine, 5 gr.; potassium bromide, 5 dwt.; water, 10 oz.; boil the silver in this usually 2 to 5 minutes, then polish with rouge.

5.—Dissolve sulphate of copper, 2 dwts.; nitrate of potash, 1 dwt.; ammonium chloride, 2 dwts., in a little acetic acid. Warm the article and apply the solution with a camel's-hair pencil and expose to the fumes of sulphur in a closed box. Parts not to be colored must be coated with wax.

6.—Dip the clean silver article in a solution of sulphide of potassium (liver of sulphur), 2 dr. to 1 pt. of water. Heat this solution to a temperature of 175° F. Immerse for a few seconds only, when the article becomes blue black. For a velvet black, dip the article, previous to oxidizing, in a solution of mercurous nitrate and water, and rinse. Then dip in the sulphide solution as above. For a brown shade, oxidize in the potassium sulphide as above, then dip in a liquid composed of 10 parts of blue vitriol and 5 parts of sal ammoniac to 100 parts of vinegar. After oxidation, brush with a scratch brush very lightly, to brighten and variegate the surface. There are many other methods.

Platinizing

Place some platinum in a small quantity of aqua regia or nitrohydrochloric acid, and keep it in a warm place for a few days, when it will have dissolved. As soon as it has dissolved, evaporate the liquid at a gentle heat until it is as thick as honey, so as to get rid of the excess of the nitric and hydrochloric acids. Add a little water, and it is ready for use. A dozen drops of this solution goes a long way in platinizing silver. The operation is performed in a small glass or beaker, covered with a watch glass to keep in the fumes, and placed in a little sand in a saucer to equalize the heat.

ZINC

Blacking

1.—Chloride of platinum, painted on zinc, gives a very dead black.

2.—Zinc may be given a fine black color, according to Knaffl, by cleaning its surface with sand and sulphuric acid and immersing for an instant in a solution composed of 4 parts of sulphate of nickel and ammonia in 40 parts of water, acidulated with 1 part of sulphuric acid, washing, and drying it. The black coating adheres firmly, and takes a bronze color under the burnisher. Brass may be stained black with a liquid containing 2 parts of arsenious acid, 4 parts of hydrochloric acid and 1 part of sulphuric acid, in 80 parts of water.

3.—A weak solution of sulphate of copper, and then with a decoction of logwood.

4.—Clean the zinc by dipping in an acid; rinse, and plunge into the following: Nickel ammonium sulphide, 4 parts; sulphuric acid, 1 part; water, 40 parts. Mix. Wash the article, and dry carefully.

5.—Treat with an acidulated solution of antimony chloride, thus: Hydrochloric acid, 6 parts; antimony chloride, 10 parts; alcohol, 100 parts. Mix. When the desired shade is attained, dry, and rub with some good drying oil. Give 2 or 3 coats.

Bronzing

1.—Mix thoroughly 30 parts of sal ammoniac, 10 parts of oxalate of potash and 1,000 parts of vinegar. Apply with a brush or rag several times until the desired tint is produced.

2.—Puscher employs acetate of lead for this purpose. On applying this substance, mixed with a minium preparation, a reddish brown tinge is obtained. The cupola of the synagogue at Nuremberg was thus colored as an experiment, a long

time ago, and to all appearance is yet unaffected by the weather. By adding other bases lighter or darker tints of gray and yellow may be obtained, giving the zinc work the appearance of carved stone. With a solution of chlorate of copper the preparation darkens the sheets of zinc.

Green Patina

1.—Make the following solution: Sodium hyposulphite, 2 parts; sulphuric acid, 1 part; water, 20 parts. Mix: filter off the precipitated sulphur, and heat the filtrate. Plunge the object into the hot solution; watch the coloration as it progresses, and when the desired tint is secured remove, let dry, and varnish with copal.

2.—Zinc Roofs.—Cleanse the zinc of all dirt, and coat it repeatedly with a diluted solution of copper nitrate. When the whole roof has been coppered over, cover it with a likewise diluted solution of carbonate of ammonia. On this coat of copper patina readily forms.

Bronzing for Zinc, by Simple Immersion.

Water.	Nitrate of iron.	Protochloride of tin.	Sulphate of copper.	Ferrous chloride.	Lead chloride.	Pearlash.	Sulphocyanide of potassium.	Hyposulphite of soda.	Garancine infusion.	Logwood infusion.	
pt.	dr.	dr.	dr.	dr.	oz.	oz.	dr.	dr.			
1	5	..	..	..	..	..	..	..	..	..	Black.
1	..	1	..	..	..	..	..	..	..	..	Black.
1	..	1	..	..	..	..	1	..	..	..	Dark gray.
2	..	..	1	1	..	..	..	..	..	..	Dark gray.
..	..	..	..	..	×*	..	..	..	..	..	Dark gray.
2	..	..	..	1	..	..	..	..	..	..	Green gray.
..	..	..	..	..	..	..	..	..	×	..	Red—Boil.
1	..	..	4	..	..	4	..	..	..	..	Copper color. Plates so c A z
1	..	..	8	..	..	..	..	8	..	..	Copper color, with agitation.
..	..	..	..	..	..	..	..	..	..	×	Purple—Boil.

*Made to the consistency of cream.

CHAPTER V.

ELECTROMETALLURGY AND HOT AND COLD COATING OF METALS

PRELIMINARY TREATMENT

Electrometallurgy has two departments, which are distinguished by the preparation of the surfaces to be coated.

Electroplating is the production of adhesive deposits, and depends on the absolute cleanness of the metal surface coated. This will be treated first.

Cleansing

1.—Copper, brass, zinc and the noble metals are cleaned by the suitable acids which act on them. Such cleaning solutions may be prepared for different metals as follows:

	Water.	Nitric.	Sulphuric.	Hydrochloric
For copper and brass	100	50	100	2
ron	100	3	8	2
Iron (cast)	100	3	12	3
Zinc	100	..	10	..
Silver	100	10	..	..

It is best to make two such solutions, one being reserved for a final dip, during which a strong action occurs upon the surface. As this becomes weaker it can be used for the first cleansing, accompanied by occasional rubbing with sand, etc., according to the nature of the object.

Lead, tin and pewter must not be placed in acid, but are cleaned by aid of caustic soda.

Objects must be carefully freed from acids if they are to be transferred to silver or gold solutions, but less care is necessary for objects cleaned in soda, nor is the same care necessary in transferring objects cleaned in acids to an acid coppering solution. In such cases the best plan is to dip into clean water and at once transfer to the depositing cell.

2.—Cleansing and Preparing Objects for Electroplating.—The first and most important operation in the electro-deposition of one metal upon another is to effect a thorough chemical cleansing of the surface of the metal upon which the coating is to be deposited, for if this is not accomplished the deposited metal will not adhere to the surface.

In cleansing, different metals usually require a somewhat different treatment. The surface of most metals, when clean, soon becomes coated with a film of oxide when exposed to the air, especially when the surface exposed is wet, and to avoid this it is usually necessary to proceed with the plating immediately after cleansing.

Before proceeding to cleanse the articles they are usually "trussed" with copper wire to avoid the necessity of handling them during the operation or afterward, until the plating is finished. A very slight contact with the hand is often sufficient to make a second cleansing necessary.

If the article to be plated presents a smooth, finished or polished surface, the deposit will be "bright." If, on the contrary, the surface is rough or unpolished, the deposit will ordinarily have a dead luster. If left too long in the acid dips used in cleansing, the polished surface is apt to have its finish deadened. No interval should be allowed between the various operations of cleansing.

Copper and Copper Alloys.—Caustic potash, 1 lb.; soft water, 1 gal. Heat nearly to boiling in a cast-iron pot provided with a cover. Brush to remove any loosely adhering foreign matters, truss, and suspend for a time in the hot lye; usually, a few minutes will suffice if the article is not heavily lacquered. If any of its parts are joined with solder it should not be allowed to remain too long immersed, as the caustic liquid attacks solders, and their solution blackens copper. On removing, rinse thoroughly in running water. If the articles are much oxidized, pickle in a bath composed of 1 gal. of water and 1 pt. of sulphuric acid until the darker portion is removed. Rinse in running water, and dip in the following solution: Soft water, 1 gal.;

cyanide of potassium, common, 8 oz. Remove from the bath and quickly go over every part with a brush and fine pumice stone powder moistened with the cyanide solution. Some electroplaters prefer to give the articles a preliminary "brightening" dip in nitric acid, or a mixture of nitric and sulphuric acids and salt, followed by rinsing in water, but the cyanide, aided by the mechanical action of the pumice and brush, does very well without it in most cases. After the scouring dip the work momentarily in the cyanide solution, rinse quickly in running water, and transfer immediately to the plating bath. Where the article is to receive a deposit of gold or silver, its surface is usually softened by slightly amalgamating it with mercury to insure perfect adhesion of the deposited metal. The amalgamating is performed by dipping the article, after the cyanide scouring operation, for a few seconds in a solution of mercuric nitrate, 1-7 oz.; sulphuric acid, 1-5 oz.; water, 1 gal. Stir until the solution becomes clear before using. Rinse the work quickly on coming from the mercury dip, and transfer to the plating solution.

The acid, cyanide and mercury dips may be kept in glass or stoneware jars (avoid jars with lead glazing), provided with covers to prevent evaporation.

A "dead luster" is imparted to articles of copper or copper alloy by dipping them for a few minutes in a bath composed of nitric acid (36°), 20 lb.; sulphuric acid (66°), 10 lb.; salt, 1-10 lb.; zinc sulphate 1-10 lb. Mix the acids gradually, add the zinc salt, then the salt, a little at a time (out of doors to avoid the acid vapors), stir well together, and let it get cold before using. Rinse thoroughly, and pass through the cyanide before putting in the plating bath.

Iron, Cast.—Cast iron is freed from grease, etc., by dipping in a hot alkali solution used for a similar purpose with copper, and after rinsing thoroughly is pickled in water containing about 1% of sulphuric acid for several hours, then rinsed in water and scoured with fine, sharp sand or pumice and a fiber brush. It is then rinsed, and returned to the acid pickle for a short time, rinsed again, and put into the plating bath directly. If more than 1% of acid is used in the pickle the time of immersion must be shortened, otherwise the iron will be deeply corroded, and the carbon which the metal contains, and which is not affected by the acid, will not yield without a great deal of labor to the sand and brush. Cast iron does not gild or silver well by direct deposit. Copper or bronze deposits are better, though not perfect; but if the iron is tinned, the coat is adherent, and will readily receive the other metals.

Iron, Wrought.—The cleansing of wrought iron, if much oxidized, is effected in the same manner as cast iron, but it will bear a stronger pickle and a longer exposure. Whitened, filed or polished iron may be treated like steel.

Steel.—Dip in the caustic lye used for copper, etc., rinse thoroughly, scour with moistened pumice powder, rinse, and pass through the following dip: Water, 1 gal.; hydrochloric acid, 4 lb. Rinse quickly (but thoroughly) and plunge in the bath.

Clean wrought iron and steel gild well without an intermediary coating in hot electrogilding baths. It is difficult to obtain an adherent coating of silver on these metals without interposing an intermediate coating of copper or brass, which renders the further operation of silverplating easy.

Dipping Acid

This name is given to a mixture which is frequently used for imparting a bright surface to brass work. When required for dipping brass work preparatory to nickelplating it is commonly composed of sulphuric acid, 4 lb.; nitric acid, 2 lb.; water, 2 qt. In making the above mixture the nitric acid is first added to the water, and the sulphuric acid (ordinary oil of vitriol) is then to be gradually poured in, and the mixture stirred with a glass rod. When cold it is ready for use. The mixture should be kept in a stoneware vessel, which should be covered with a sheet of stout glass. The dipping should always be conducted either in an outer yard or near a fireplace, so that the fumes may escape, as they are exceedingly irritating to the lungs when inhaled. The instant the articles are removed from the dipping bath, they should be plunged in a vessel of water.

Pickling Bath

Pickling Bath.—Cast iron before nickeled requires to be placed in a cold acid solution or "pickle" to dissolve or loosen the oxide from its surface. The pickle may be prepared in a wooden tub or tank from either of the following formulæ: Sulphuric acid (oil of vitriol), ½ lb.; water, 1 gal. Cast-iron work immersed in this bath for twenty minutes to half hour will generally have its coating of oxide sufficiently loosened to be easily removed by means of a stiff brush, sand and

water. When it is desired that the articles should come out of the bath bright instead of the dull black color which they present when pickled in the plain sulphuric acid bath the following formula may be adopted: Sulphuric acid, 1 lb.; water, 1 gal. Dissolve in the above 2 oz. of zinc, which may conveniently be applied in its granulated form. When dissolved add ½ lb. of nitric acid and mix well.

The greatest care should be used in cleansing or pickling before nickeling. The fine iron work which is made at Wernigerode and other places in the Hartz Mountains, is believed to be cleansed in this manner. Work of this class is inexpensive and is very artistic.

Scratch-Brushing

The scratch brush is often resorted to to remove the dead luster on or to impart a smooth surface to an object. They are usually made of brass or steel wire, and of a variety of shapes to suit the object.

The wheel brushes are used on the lathe or grinding head, the objects being manipulated in contact with the rapidly revolving brush. The brush is usually kept moistened by a small stream of water while in use.

PLATING BY NAMES OF METAL DEPOSITED

Aluminum

1.—Aluminum may be deposited on copper from a dilute solution of the double chloride of aluminum and ammonia.

2.—Aluminum is one of the most difficult and uncertain of metals to deposit electrolytically. The following recipe is given by Herman Reinbold, who states that it furnishes excellent results: Fifty parts by weight of alum are dissolved in 300 of water and to this is added 10 parts of aluminum chloride. The solution is heated to 200° F., and when cold 39 parts of cyanide of potassium are added. A feeble current should be used.

Brass

1.—De Salzede's Process.—12 parts cyanide of potassium; 610 parts carbonate of potassium; 48 parts sulphate of zinc; 25 parts chloride of copper; 305 parts nitrate of ammonia; 5,000 parts of water. The cyanide is to be dissolved in 120 parts of the water, and the carbonate of potash, sulphate of zinc and chloride of copper are to be dissolved in the remainder of the water, the temperature of which is to be raised to about 150° F. When the salts are dissolved, the nitrate of ammonia is to be added, and the mixture well stirred until the latter is all dissolved. The solution should be allowed to stand for several days before using, and the clear liquor separated from any sediment that may have deposited at the bottom of the vessel.

2.—Cyanide of potassium, 50 parts; carbonate of potassium, 500 parts; sulphate of zinc, 35 parts; chloride of copper, 15 parts; water, 5,000 parts. This solution is to be made up in the same way as No. 1.

3.—Bronzing Solution.—This solution is the same as No. 1, except that 25 parts chloride of tin are substituted for the sulphate of zinc.

4.—Bronzing Solution.—This is the same as No. 2, with the exception that 12 parts chloride of tin are substituted for the sulphate of zinc. This solution is worked warm, that is, at about 97° F.

The Brass Bathsh.—a.—Where the ordinary cheap commercial cyanide is employed, the following answers very well; Sulphate of copper, 4 oz.; sulphate of zinc, 4 to 5 oz.; water, 1 gal.

Dissolve and precipitate with 30 oz. carbonate of soda; allow to settle, decant the clear liquid, and wash the precipitate several times with fresh water—after as many settings. Add to the washed precipitates: Carbonate of soda, 15 oz.; bisulphite of soda, 7½ oz.; water, 1 gal.

Stir to effect solution of these last two, then stir in ordinary cyanide of potassium until the liquid becomes clear and colorless. Filter if much iron or iron oxide (derived from impure zinc salt and cyanide) remains suspended in the liquid. An additional ½ oz. or so of the cyanide improves the conductivity of the solution.

b.—Management of the Bath.—The losses of the bath are to be repaired by the addition of copper and zinc salts (and arsenious acid) dissolved in fresh cyanide and water.

The operator determines the requirements from the rapidity of the deposit, its condition, color, etc.

The difficulty in brass electrotyping, especially with small baths, is in keeping the uniformity of the color of the deposit, as the electric current, having to decompose two salts, each offering a different resistance, must, according to its intensity, vary the color and composition of the deposit. A feeble current principally decomposes the copper salt and results in a red deposit; while too great intensity in the current decomposes the zinc salt too rapidly and the deposit is a white or bluish white alloy. If the deposit has an

earthy or ocherous appearance, or if the liquid is blue or greenish, the solution is deficient in cyanide. When in proper working order the liquor is colorless. If the coating becomes dull and unequal, a slight addition of arsenious acid will usually improve it.

If the deposit is too red, use more battery power or add more zinc salt; if too white, decrease the current or add more copper salt. The specific gravity of the bath may vary from 5° to 12° Baumé; when it exceeds this latter gravity it should be diluted with fresh water to decrease the electric resistance.

If the brass deposit is irregular, remove the articles from the bath, rinse, scratch-brush, and put again into the bath, until the color and thickness of the deposit are satisfactory. Scratch-brush again, and, if necessary, rinse in hot water, dry in warm white wood sawdust, and put in the stove room. The last three operations are indispensable for hollow pieces.

In the disposition of the brass plating bath it is always necessary to have all the articles suspended at about equal distances from the anodes.

The bath may be subdivided by several anodes, forming partitions, so that each loaded rod is between two anodes.

The anodes should always be removed when the bath is not in use.

In order that the brass electroplating of zinc or copper may be lasting the deposit must not be too thin, and must be scratch-brushed, washed in lime water, and dried in the stove room.

Generally ten to twenty-five minutes' exposure in the bath suffices in ordinary practice to throw on a good coating. Cast and wrought iron, lead and its alloys require a bath richer in the metals than when brassplating zinc or its alloys. The battery power should also be greater. For lead the bath works better warm (at about 90° F.). When once placed in the brass bath articles should not be moved about, as there is a tendency under such circumstances to the formation of a red deposit.

In brassplating wire the hot bath is usually employed. As before mentioned, the vessel containing the bath usually consists in an oblong open iron boiler, lined with sheet brass anodes, and heated by fire, steam or hot water. A stout copper or brass rod in the direction of the length of the boiler rests upon the edges, from contact with which it is insulated by pieces of rubber tubing. The rod is connected with the zinc pole of the battery. The binding wires are removed from the coil, the wires loosened, and the ends bent together into a loop. The wire is then dipped into a pickle of dilute sulphuric acid, and hung upon a stout round wooden peg fastened in the wall, so that the coil may be made to rotate easily. After a scrubbing with wet sharp sand and a hard brush the coil is given a primary coating of copper. It is then suspended to the horizontal rod, where only a part of the coil at a time dips into the solution and receives the deposit. The coil is then turned now and then one-half or one-fourth its circumference. By dipping the coil entirely into the liquid the operation is not so successful.

The wires are washed, dried in sawdust, and then in the stove room, and lastly passed through a draw plate to give them the fine polish of true brass wires.

The temperature at which the hot bath is commonly used varies between 130° and 140° F.

Bronze Baths

1.—Potassic cyanide, 50 parts; potassic carbonate, 500 parts; tin chloride, 12 parts; cupric chloride, 15 parts; water, 5,000 parts. This bath is used at a temperature not exceeding 36° C.

2.—Bronzing Electro-brassed Work, Green Bronze.—Mix into a paste with water the following substances: Chromate of lead (chrome yellow), 2 oz.; Prussian blue, 2 oz.; plumbago, ½ lb.; sienna powder, ¼ lb.; lac carmine, ¼ lb. When applying the above composition a small quantity of sulphide of ammonia or chloride of platinum solution may be added.

3.—Solutions for Depositing Brass or Bronze; Dr. Heeren's Process.—A brassing solution may be prepared by employing a large excess of zinc to a very small proportion of copper as follows: Sulphate of copper, 1 part; sulphate of zinc, 8 parts; cyanide of potassium, 18 parts. The ingredients are to be dissolved in separate portions of warm water. The copper and zinc solutions are to be mixed and the cyanide solution then added, when 250 parts of distilled water are to be added and the mixture well stirred. The bath is to be used at the boiling temperature with two Bunsen cells. By this process, it is said that very rapid deposits of brass have been obtained upon articles of copper, zinc, Britannia metal, etc.

4.—French Method of Bronzing Electro-brassed Zinc Work; Steel Bronze.—This is obtained by moistening the articles with a dilute solution of chloride of

platinum and slightly heating them. Since this bronze is liable to scale off with friction, it should not be applied in successive doses, but the solution used should be of such a strength that the desired effect may be obtained if possible by a single application. Copper bronze, that is electro-brass with an excess of copper, may be darkened by dipping it into a warm and weak solution of chloride of antimony (butter of antimony) in hydrochloric acid. Sometimes the color will be violet instead of black.

5.—French Method of Bronzing Electro-brassed Zinc Work; Green or Antique Bronze.—Dissolve in 100 parts of acetic acid or in 200 parts of good vinegar, 30 parts of carbonate of ammonia or sal ammoniac, and 10 parts each of common salt, cream of tartar and acetate of copper and add a little water. Mix well and smear the object with it, allow it to dry at the ordinary temperature, from twenty-four to forty-eight hours. At the end of that time the article will be found to be entirely covered with verdigris, which presents various tints. It is then to be brushed, but more especially the prominent parts, with a waxed brush, that is a brush passed over a lump of yellow beeswax. The relief parts may then be "set off" with hematite, chrome yellow, or other suitable colors. Light touches with ammonia impart a blue shade to the green parts; carbonate of ammonia deepens the color.

Copper

1.—Where it is intended to simply coat or plate another metal or alloy, the electro deposit of copper is usually obtained by the decomposition of a double salt, such as the cyanide of copper and potassium. This process is adapted to most metals, and affords a fine uniform deposit. The following is a good bath of this description: Water (soft), 1 gal.; acetate of copper (cryst.), 3½ oz.; carbonate of soda (cryst.), 3½ oz.; bisulphate of soda, 3 oz.; cyanide of potassium (pure), 7½ oz.

Moisten the copper salt with water to form a paste (otherwise it is apt to float on the liquid); stir in the next carbonate of soda with a little more water, then the bisulphite, and finally the cyanide with the rest of the water. When solution is complete the liquid should be colorless. If not, add cyanide until it is.

The bath may be employed hot or cold, and requires a moderately strong circuit of electricity. A copper plate forms the anode, and it should expose surface enough to supply the loss of copper—at least a surface equal to that of the work. It must be removed when the bath is not in use.

If the liquid becomes colored, more cyanide must be added.

Large pieces are generally kept hanging motionless in the bath while the plating is in progress; small articles are moved about as much as possible, especially if the bath is warm.

The formula for the bath given above requires pure cyanide of potassium, and where the commercial article, which is often very impure, is used instead, considerable allowance must be made.

2.—Alkaline Copper Solution.—The best alkaline copper solution is that introduced by Mr. A. Watt, and subsequently modified by Mr. J. T. Sprague. Dissolve 8 oz. of copper sulphate in 1 qt. hot rain water and set aside to cool. When cool, add liquid ammonia, while stirring with a stick or glass rod. At first a green precipitate will fall, and then this will dissolve on adding more ammonia, until the whole solution assumes a lovely blue tint. Dilute this with an equal bulk of cold rain water, and add to it enough solution of potassium cyanide, while stirring, to destroy the fine blue color of the ammonia sulphate and give the color of old ale to the solution. Set this aside for a few hours, then pass it through a calico filter and make it up to a gallon of solution with rain water. This solution may be worked cold, but the rate of deposition is increased and the deposited copper of improved quality when the solution is heated to a temperature of from 110° to 130° F.

3.—Aluminum.—a.—Copper cyanide, 6 parts; potassium cyanide, 9 parts; sodium phosphate, 9 parts; distilled water, 100 parts.

b.—According to a Continental contemporary, it is possible to obtain adhesive coats of copper on aluminum by the following method: First clean the aluminum in a warm solution of alkaline carbonate, thus making its surface rough and porous; it is next washed thoroughly in running water, and dipped into a hot solution of hydrochloric acid of about 5 per cent. strength, again washed in clean water, and then placed in a somewhat concentrated acid solution of copper sulphate, until a uniform metallic deposit is formed; it is then again thoroughly washed and returned to the copper sulphate bath, when an electric current is passed until a coating of copper of the required thickness is obtained.

4.—Eectrotyping Non-conducting Materials, New Process for.—For electrotyp-

ing on non-conducting materials, such as china and porcelain, a new and ingenious process has been lately introduced in France. Sulphur is dissolved in oil of spike lavender to a syrupy consistency; then chloride of gold or chloride of platinum is dissolved in ether, and the two solutions mixed under a gentle heat. The compound is next evaporated until of the thickness of ordinary paint, in which condition it is applied with a brush to such portions of the china, glass, or other fabric as it is desired to cover, according to the design or pattern, with the electro-metallic deposit. The objects are baked in the usual way before they are immersed in the bath.

5.—Electro-coppering Flowers, Insects, etc.—To render non-metallic substances conductive (Parkes).

a.—A mixture is made from the following ingredients: Wax or tallow, 1 oz.; india-rubber, 1 dram; asphalt, 1 oz.; spirit of turpentine, 1½ fl.oz. The india-rubber and asphalt are to be dissolved in the turpentine, the wax is then to be melted, and the former added to it and incorporated by stirring. To this is added 1 oz. of a solution of phosphorus in bisulphide of carbon in the proportion of 1 part of the former to 15 parts of the latter. The articles being attached to a wire are dipped in this mixture; they are next dipped in a weak solution of nitrate of silver, and when the black appearance of the silver is fully developed the article is washed in water; it is afterward dipped in a weak solution of chloride of gold and again washed. Being now coated with a film of gold, it is ready for immersion in the copper bath.

b.—Wax and deer's fat, of each ¼ lb. Melt together and add phosphorus, 10 grams, dissolved in bisulphide of carbon, 150 grams. The wax mixture must be allowed to become nearly cool, when the phosphorus solution is to be added very carefully through a tube dipping under the surface of the mixture. Stir thoroughly. Molds prepared from this composition are rendered conductive by being first dipped in a solution of nitrate of silver, then rinsed, and afterward dipped in a weak solution of chloride of gold, and again washed, when they are ready for the coppering solution.

6.—Iron and Steel.—The following formulæ require a cyanide containing 70 to 75% (a good average) of pure potassium cyanide.

a.—Cold Bath.—Acetate of copper, 3 oz.; carbonate of soda, 6 1-5 oz.; bisulphite of soda, 3 1-5 oz.; cyanide of potassium, 3¼ oz.; water, 1 gal.; aqua ammonia, 2 1-5 fl.oz. Prepare as before.

b.—Warm Bath.—Acetate of copper, 3 1-5 oz.; carbonate of soda, 3 1-5 oz.; bisulphite of soda, 1 1-5 oz.; cyanide of potassium, 4½ oz.; water, 1 gal.; aqua ammonia, 1 4-5 fl.oz.

7.—Zinc.—For small articles of zinc, which are coppered in a perforated ladle and in nearly boiling baths: Acetate of copper, 16 oz.; bisulphite of soda, 3½ oz.; cyanide of potassium, 25 oz.; aqua ammonia, 5½ oz.; water, 4 to 5½ gal.

In the preparation of these baths the salts are all dissolved together, except the copper acetate and ammonia, which are added after dissolving together in a small quantity of the water.

The deep blue color of the ammonia-copper solution should entirely disappear on mixing it with the other solution; otherwise it becomes necessary to add more cyanide.

The cold bath is put into well joined tanks of oak or fir wood, coated inside with gutta percha or asphaltum (genuine). The vertical sides are also covered with sheets of copper, all connected with the last carbon or copper of the battery by a stout copper wire with well cleaned ends, the other pole of the battery being in similar connection with a stout brass rod extending the length of the tank (without any point of contact with the anodes), and from which the work is suspended by hooks or trusses in the bath.

With a thin deposit the coating is sufficiently bright to be considered finished after being rinsed and dried. But if the operation is more protracted the deposit has a dead luster on account of its thickness, and if a bright luster is desired it is necessary to use the scratch-brush.

The hot baths are usually put into stoneware vessels heated by a water or steam bath, or into an enameled cast-iron kettle placed directly over a fire. The vessels are lined inside with copper, the edges of the vessel being varnished, or support a wooden ring upon which rests a brass circle connected with the zinc pole of the battery. The objects to be electroplated are suspended from this ring.

The hot process is more rapid than the cold, and is especially adapted to those articles which are difficult to cleanse. The articles are kept in continual agitation, which permits of the employment of a strong current of electricity. Small articles of zinc are placed in a perforated stoneware or enameled ladle, at the bottom of which is attached a copper wire which is wound up around the handle and connected with the zinc pole of the battery. It is sufficient that one of the

small articles touches the wire for all to be affected by the current, as they are in contact with each other. The ladle must be continually agitated, so as to change the points of contact of the objects. What has been said in regard to electro brassplating will apply here.

Gold

1.—In the practice of electroplating with gold the bath employed is usually heated, as the deposits obtained in such a bath are more homogeneous, tenacious and durable, and of a better color, besides which recommendation a greater quantity of metal may be deposited satisfactorily from it in a given time than from a cold bath.

Owing to the cost of the metal to be deposited very large surfaces are rarely required to be electroplated, and as these baths become worn out and must be replaced by fresh solutions after a short time, they are usually, as a matter of economy and convenience, used in as small a vessel as the circumstances will admit of. These vessels may be of glass, porcelain, or porcelain-enameled iron. The latter serve the purpose admirably (if the enamel is good). They should be heated over the water bath or by means of steam.

The same bath does not answer very well for all metals—either the bath must be modified to suit the metal or the latter must be previously coated with another metal to suit the conditions. Gold deposits are obtained with the greatest facility upon silver or copper, their rich alloys, or other metals coated with them. With these a hot bath (at about 170° F.) and a moderately strong current give good results. With alloys, such as German silver, the best results are obtained with a weak bath, barely warm. Steel and iron, when not coated with copper, require an intense current and a very hot bath. Lead, zinc, tin, antimony and bismuth alloys of, or containing much of these, are preferably coated with copper before electrogilding.

2.—Operations Connected with Electrodeposition.—Solution for protecting plated work, which is to be gilded in a hot cyanide bath, from receiving the gold deposit upon parts of the ornamental work: Clear rosin, 10 parts; yellow beeswax, 6 parts; best red sealing wax, 4 parts; jeweler's rouge, 3 parts. The three first named substances are to be thoroughly melted with gentle stirring, and the rouge, which is the peroxide of iron, gradually added and incorporated with stirring. The article to which the stopping-off varnish has been applied should never be placed either in a hot or cold bath until it has become thoroughly dry and hard.

Aluminum.—Gold chloride, 2 parts; potassium cyanide, 2 parts; sodium phosphate, 2 parts; water, distilled, 100 parts.

Amateurs' Gilding Solution.—The best and cheapest solution for amateur electrogilding, and also for operators in a small way of business, is the double cyanide of gold and potassium solution made by the battery process. This contains some oxide of potash, but if made up of pure gold and pure 98% cyanide of potassium, it will yield good results at once, and continue to give them for years if kept in proper working condition. This solution is made up in the following manner: Procure 5 dwts. pure gold ribbon, leaf, or wire (and divide it into 2 parts), 3 dwts. pure white 98% cyanide of potassium and 1 qt. of distilled water. Dissolve the cyanide of potassium in the distilled water made hot in a good enameled saucepan, and keep it at nearly scalding heat while making and working the gilding solution. Make up a battery of two Bunsen cells or three Daniel cells in series. Hang one strip of gold from the wire leading to the negative element of the battery, and the other strip to the wire leading to the positive element of the battery. Get a small, clean, white porous battery cell, nearly fill it with cyanide of potassium solution, place it in the saucepan and suspend in the porous cell the strip of gold connected to the zinc element of the battery. Immerse the other strip of gold in the outer cyanide solution, and pass current (from the battery) from one to the other for some two or three hours. During that time some of the gold will have dissolved off the anode strip and entered into combination with the cyanide of potassium solution to form the double cyanide of gold and potassium gilding bath, but this will not have penetrated into the porous cell, nor will the strip of gold therein have suffered any loss. If at the end of this time a piece of German silver, suspended from the cathode wire in the outer solution, receives a fair coat of gold in a few moments, the bath is ready for gilding work. The contents of the porous cell may be poured into the outer solution, both strips of gold used as the anode, and the work may proceed with current from one or more cells, as may be required. At first there may be too much free cyanide, and the deposit may in consequence be too dark, but this fault will soon be corrected if the anode plates are wholly immersed

while gilding. If the contrary condition exists, and the anode plates are dirty, or do not dissolve freely, add a very little more cyanide to the solution. This will be found to be the cheapest solution, because there is no loss of material in making it up. If the whole of the gold strip dissolves in the cyanide solution, the bath will not be too rich in gold, as a very useful strength is 2 dwts. of gold in the quart of solution. A larger quantity may be made in the same manner in the same proportions.

Brass.—Jewelry.—1.—For Producing a Matted Surface on Brass Articles of Jewelry, as Brooches, Lockets, etc.—First dip them for an instant in a mixture composed of equal parts of sulphuric and nitric acids, to which a small quantity of common salt is added; plunge immediately in cold water. Rinse in one or two other waters, then immerse in the gilding bath, in which, after a moment's immersion, they acquire the desired color of gold. After rinsing in hot water they are finally dried in hot boxwood sawdust.

2.—French Gilding for Cheap Jewelry.—The bath for gilding recommended by Roseleur is composed of pryophosphate of soda or potassa, 800 grams; hydrocyanic acid (prussic acid), 8 grams; chloride of gold crystallized, 20 grams; distilled water, 10 liters. The pyrophosphate of soda is generally employed and this may be prepared by melting at a white heat ordinary crystallized phosphate of soda in a crucible. The quantity of gold given in the above formula represents the grams of the pure metal dissolved by aqua regia. In making the bath 9 liters of water are put into a porcelain vessel and the pyrophosphate added, with stirring a little at a time, moderate heat being applied until all the salt is dissolved. The solution is then filtered and allowed to cool. The chloride of gold is allowed to crystallize, the crystals dissolved in a little distilled water, and the solution filtered. Add the chloride solution to the cold solution of pyrophosphate of soda, then add the hydrocyanic acid and heat to near boiling point.

This bath will produce fine gilding upon well cleaned articles, which must also have been passed through a very diluted solution of nitrate of mercury, without which the deposit of gold is red and irregular. The articles must be constantly agitated in the bath, and supported by a hook, or placed in a stoneware ladle perforated with holes.

Cold Electrogilding Bath.—Water, distilled, 1 gal.; potassium cyanide, pure, 3 1-5 oz.; gold chloride, 3 1-10 oz.

Dissolve the cyanide in a part of the water, then gradually add the gold chloride dissolved in the remainder. Boil for half an hour before using. (Use cold.)

The cold bath is kept in a gutta percha lined, wooden, or (if small) porcelain tank arranged as for brassplating. The anodes are thin plates of laminated gold, wholly suspended in the liquid (while in use) by means of platinum wires, from clean brass rods joined to the copper or carbon pole of the battery, the rods supporting the work being in connection with the zinc. When in proper working order the color of the deposit is yellow. If the deposit becomes black or dark red, add more cyanide (dissolved in water) to the bath, or use a weaker current.

If the cyanide is in excess the plating will proceed very slowly or not at all; or, as sometimes happens, articles already gilded will lose their gold. In such a case add a little more gold chloride or increase the intensity of the current.

Cold electrogilding must be done slowly, and requires a great deal of attention to secure good work. The articles must be frequently examined to detect irregular deposits or dark spots (which must be scratch-brushed and returned). It is also frequently necessary to add to or remove an element from the battery especially when adding or taking work from the bath. With too much intensity of current the deposit is black or red; if too weak those portions opposite the anode only get covered. In coating German silver it is necessary to use a weak bath and a small exposure of anode. The best results with this alloy are obtained when the bath is slightly warmed.

Hot Baths.—1.—For copper, silver, or alloys rich in these.—Distilled water, 1 gal.; phosphate of soda, cryst., 9½ oz.; bisulphite of soda, 1 3-5 oz.; cyanide of potassium, pure, 1-6 oz.; gold chloride, 160 gr.

Dissolve in a portion of the water, heated, the phosphate of soda. Dissolve in another portion of the water the bisulphite of soda and cyanide of potassium. Dissolve the gold chloride in the remaining water, stir the solution slowly into the cold phosphate of soda solution, and finally add the solution of cyanide and bisulphite. The bath, now ready for use, should be colorless.

2.—Bronze and Brass.—a.—The following baths work well with bronze and brass, but are not suited for direct gilding on iron or steel: Distilled water, 1 gal.; phosphate of soda, cryst., 6 2-5 oz.; bisulphite of soda, 1 3-5 oz.; bicarbonate

of potash, 4-5 oz.; caustic soda, 4-5 oz.; cyanide of potassium, pure, 1-5 oz.; gold chloride, 2-5 oz.

Dissolve all together, except the gold chloride, in the hot water; filter, cool and gradually stir in the gold chloride dissolved in a little water. Heat from 120° to 140° F. for use. It requires an intense current.

b.—Distilled water, 1 gal.; ferrocyanide of potassium, 5¼ oz.; carbonate of potash, pure, 1¾ oz.; sal ammoniac, 2-3 oz.; gold chloride, 2-3 oz.

Dissolve as in the last, boil for half an hour, replace the evaporated water, and the bath is ready for use.

c.—Distilled water, 1 gal.; cyanide of potassium, 2 4 5 oz.; gold chloride, 1 oz.

Dissolve the gold chloride in the water, then add the cyanide, and stir until solution is complete.

Baths of this kind are commonly used, and with little regard to temperature. They are simple in preparation, but are, unfortunately, not very uniform in their working, ungilding one part while another is gilding, and producing a variety of colors, especially when freshly prepared. They improve by use, however.

3.—Iron and Steel—Uncoated, Bath for.—Distilled water, 1 gal.; phosphate of soda, cryst., 7 8 10 oz.; bisulphite of soda, 2 oz.; cyanide of potassium, pure, 3-5 drams; gold chloride. 160 grains.

Dissolve as before. Heat to 175° or 180° F. Pass the second metal through the hot potash, then through dilute muriatic acid (acid 1, water 15), brush, and connect at once. Requires a very intense current at first.

4.—Management of the Hot Bath.—The articles should be kept in agitation while in the bath. They should be placed in connection with the battery before or immediately upon entering the bath. A foil or wire platinum is in many cases preferable to a soluble gold anode when electrogilding by aid of heat. It suffers no alteration in the liquid, and by its manipulation the color of the deposit may be materially altered. When it is removed so as to expose only a small surface in the bath a pale yellowish deposit may be obtained; when the immersion is greater, a clear yellow; with a still greater exposure, a red gold color. The strength of the hot baths may be maintained by successive additions of gold chloride with a proper proportion of the other salts and water; but it is preferable to wear out the bath entirely and prepare a new one, as it soon becomes contaminated with copper or silver if much of these metals have been gilt in it. In a nearly exhausted bath containing dissolved copper the electro deposit will be what is called "red gold"; if it contains an excess of silver a "green gold" deposit will result. The gold and copper or gold and silver are deposited together as an alloy, the color of which depends upon the relative proportion of the metals, battery, strength, etc.

Dead luster gilding is produced by the slow deposition of a considerable quantity of gold, by giving the metallic surface a dead luster before gilding (by means of acids), by first preparing a coating of frosted silver or by depositing the gold upon a heavy copper deposit produced with a weak current in a bath of copper sulphate.

In order to secure a good deposit of gold it is absolutely necessary that the work should be perfectly freed from any trace of oxide, grease, oil, or other impurity. Articles of copper and brass may be cleansed by first immersing them in a strong boiling solution of caustic potash or soda, and, after rinsing, dipping momentarily in nitric acid and immediately rinsing, or scouring with pumice stone moistened with a strong solution of cyanide of potasium in water.

Other metals require a somewhat different treatment, which we shall have occasion to refer to in a subsequent article.

Lead, Britannia Metal, etc.—When articles composed of lead, tin, Britannia metal, iron or steel are required to be gilded it is best to give them a preliminary coating of copper in an alkaline bath, or to electro brass them, after which they may be easily gilded. The softer metals need to be burnished with great care, owing to their yielding nature under the pressure of the burnishing tools.

Steel, Polished.—For gilding polished steel, a nearly neutral solution of chloride of gold is mixed with sulphuric ether and well shaken. The ether will take up the gold and the etheral solution float above the denser acid. If the ethereal solution be applied by means of a camel's hair brush to brightly polished steel or iron, the ether evaporates and the gold, which adheres more or less firmly, becomes reduced to the metallic state on the steel, and may be either polished or burnished. Steel receives a deposit of gold with great rapidity, even with a very weak battery current.

Iron

Electro-deposition of Iron, Solutions for.—1. Ammonia Sulphate of Iron Solution.—This double salt, which was first

proposed by Boettger, for depositing this metal, may be readily prepared by evaporating and crystallizing mixed solutions of equal parts of sulphate of iron and sulphate of ammonia. A solution of the double salt yields a fine white deposit of iron, with a moderate current, and has been very extensively employed in "facing" engraved copper plates. When carefully worked this is one of the best solutions for the deposition of iron upon copper surfaces.

2.—Boettger's Ferrocyanide Solution.—This solution for coating engraved copper plates with iron is formed by dissolving 10 grams of ferrocyanide of potassium (yellow prussiate of potash) and 20 gr. of Rochelle salts in 200 cubic centimeters of distilled water. To this solution is added a solution consisting of 3 grams of persulphate of iron in 50 cubic centimeters of water. A solution of caustic soda is then added drop by drop, with constant stirring, until a perfectly clear, light, yellowish liquid is obtained, which is ready for immediate use.

Boettger's process, as far as we are aware, has never been improved on. It is as follows: Mix 10 parts of ferrous ammonium chloride and dissolve the mixture in 500 parts of distilled water. Render the solution slightly, but distinctly acid by the addition of sulphuric acid drop by drop. The surface to be plated is connected with the negative pole of a battery, an iron plate of equal size being connected with the positive pole and serving as an anode. For small articles two or three Bunsen elements will answer very well. Maintain the solution at from 75° to 80° F. The deposited iron is very pure, white, very hard and steel-like, and accumulates very rapidly. In this manner copper, zinc, type metal, etc., may be given a surface as hard as steel plate and at a minimum cost. Of course the article to be plated should be rendered perfectly clean before it is put into the bath.

3.—Copper.—Prof. Boetgger recommend the following solution for coating copper plates with iron: 10 parts of ferrocyanide of potassium and 20 parts of tartrate of soda are dissolved in 220 parts of distilled water, adding a solution of 3 parts of sulphate of iron in 50 parts of water. Caustic soda solution is poured into the mixture until the Prussian blue formed is redissolved.

Nickel

Preparation of Nickel Solution.—**1.** The substance generally employed is the double sulphate of nickel and ammonia, or "nickel salts," a crystalline salt of a beautiful green emerald color. This article should be pure. For 100 gal. of the solution the proportions employed are: Double sulphate of nickel and ammonia, 75 lb.; water, 100 gal. Place the nickel salts in a clean wooden tub or bucket and pour upon them a quantity of hot or boiling water; stir briskly with a wooden stick for a few minutes, after which the green solution may be poured into the tank, and a fresh supply of hot water added to the undissolved crystals, with stirring as before. This operation is to be continued until all the crystals are dissolved, and the solution transferred to the tank. A sufficient quantity of cold water is now to be added to make up 100 gal. in all. It is better to pass the hot solution through a strainer before it enters the tank, to free it from impurities.

2.—Nickelplating.—The Plating Bath.—The nickel salts commonly used are the nickel ammonium sulphate (called double sulphate) and the corresponding chloride. Other salts, such as the nickel potassium cyanide, the acetate and sulphate, have been used, but not so successfully as these.

The double sulphate bath may be prepared by dissolving ¾ lb. of the salt in each gallon of water (soft). The salt costs about 65 cents a pound, and is generally considered the best for this purpose. It should be kept neutral and up to about 6° of hydrometer.

The double chloride bath requires about 4 oz. of the salt per gallon, and works better toward alkalinity.

The bath should be filtered when freshly prepared, and should be kept in a separate room, or at least away from the apartment in which the buffing or polishing is performed, to avoid contamination by dust as much as possible. Exposed to the air, the bath (the water) evaporates, and the water thus lost must be replaced from time to time. To retard this and keep out dust as much as possible, it is well to cover the bath when not in use. Its surface should be skimmed occasionally and it should be frequently mixed together to preserve a uniform degree of strength.

The tank or vessel in which the bath is contained is usually constructed of smooth 2-in. white pine stuff, grooved and well bolted together and coated on the inside with good asphaltum applied in the melted state.

Instead of this form, a clean tub or a half barrel or hogshead, with an extra hoop, may be used, though from the shape

of such a vessel there is necessarily much waste space to be filled with useless liquid.

For small baths a neat form of vessel consisting in a square porcelain lined (enameled) iron tank of suitable dimensions is sold by some of the dealers in electroplating materials.

3.—Anodes of Feeding Plates.—Good pure cast nickel anodes are now obtained at a moderate cost, and are preferable to grain metal anodes. They usually come in sizes ranging from 1¾ x 4 in., 3-16 in. thick, to 8 x 12 in., ⅝ in. thick.

They may be suspended around the sides of the tank or across and facing the work (care being taken to avoid bringng them into such close proximity to the work that contact is likely to occur under any circumstance). They may be suspended by clean copper trusses or hooks —which should not be permitted to touch the liquid—from stout copper rods, to which connection with the battery is made.

4.—The Battery.—In nearly all large electroplating establishments some form of dynamo-electric machine is now used instead of the battery. They are cleanly, require little attention and space, and afford a current more easily adapted to the work and at a much smaller cost.

But as their first cost is considerable, and they require power to operate them, the old battery is still in requisition in smaller establishments. The carbon or chromic acid battery is more commonly used, as it admits of more rapid work with a smaller number of cells; but as it supplies a very intense current, it often becomes necessary to introduce resistance coils to reduce it where small work is on hand. Some of the best work we have ever seen has been produced with the current derived from two or three Smee or sulphate of copper cells (in series). The amount of battery power for a given amount of work should be in zinc surface (exposed) about equal (when in proper working order) to the surface of the work exposed in the plating bath, with care to preserve the tension. If one cell has a zinc surface (exposed) of, say, one hundred square inches, and the work, say, five hundred, the one cell will require to be multiplied by five for quantity and (if the original tension was, say, three) by three to preserve the tension.

Of course this is equivalent to three large single cells, each exposing five hundred square inches of zinc (equal to a plate about sixteen inches square, exposing both sides). Large batteries of the dipping form, admitting of the immersion of the proper quantity of zinc, are often convenient.

If the current is too strong the deposited metal will present a dull (commonly termed burnt) appearance; if too weak it is apt to be imperfect, granular, or semi-crystalline.

For practical purposes the electricity may be said to proceed from the copper or carbon pole of the battery, and care should be taken that this pole is invariably connected (by stout copper wires or rods) with the anodes or feeding plates in the plating bath, for if misconnected damage is done both to the work and the bath by the corrosion or partial solution of the former in the latter.

5.—Preparing the Work.—Before work can be plated its surface must be freed perfectly from all traces of oil or grease, oxides, lacquer, and other impurities. Oil, grease, etc., are removed by contact with a strong, hot acqueous solution of caustic potash, and, after rinsing off the adhering alkali, from oxide by an acid bath; or, if of brass, copper, or German silver, by scouring with fine pumice stone and strong acqueous solution of cyanide of potassium. Iron is pickled in diluted sulphuric or muriatic acid (acid 1, water 5 to 15), and scoured with fine white silicious sand or pumice stone. Brass or copper is sometimes brightened before entering to the plating bath by dipping it momentarily in nitric acid diluted with about 20 parts of water, and quickly rinsing it in running water. It should be placed in circuit immediately after this.

The hand must not come into contact with any part of the work after removal from the alkali, as the slightest touch may spoil all.

On removal of the plated work from the plating bath it should be quickly rinsed (without handling) in cold water, then transferred to hot water, which will cause it when taken out to dry quickly and perfectly. If the finished work is to present a smooth polishing surface it must present such a surface before entering the plating bath. Nickel is hard and will not readily submit to a burnishing tool.

When the work is placed in circuit in the plating bath (and it should not be permitted to remain many moments in the bath without being placed in circuit) it should be moved about to free it from bubbles.

The process of nickelplating is a simple one, and by a little practice and proper attention to the requirements the

bath may be worked month after month, and the metal deposited smoothly and with certainty.

Formulae for Nickelplating Solutions. 1.—Double sulphate of nickel and ammonium, 5 to 8 parts; water, 100 ports.

Dissolve the nickel double salt in above quantity of water with the aid of heat. Cautiously add ammonia, or the sulphate of ammonium, until the solution is neutral to test paper. This solution should be maintained as nearly neutral as possible in use. This is commonly known in the United States as the Adams solution. It is in very general use by nickelplaters throughout the United States, and yields, where properly managed, excellent results.

2.—Double sulphate of nickel and ammonium, 10 parts; boric acid (refined 2½ to 5 parts; water, 150 to 200 parts.

(Weston's solution.) The superiority of this solution is generally acknowledged. The deposited metal, as previously remarked, is almost silver-white, dense, homogenous and tenacious, and the solution maintains its excellent working quality very uniformly in long-continued service.

The nickel salt and boric acid may be dissolved separately in boiling water, the solutions mixed, and the volume brought up to that of the formula, or the two components may be dissolved together.

3.—Acetate of nickel, 2¾ parts; acetate of calcium, 2½ parts; water, 100 parts.

To each gallon of this solution add 1 fl. oz. of acetic acid, 1.047 sp. gr.

To prepare this bath dissolve about the same quantity of the dry carbonate of nickel as that called for in the formula (or three-quarters of that quantity of the hydrated oxide) in acetic acid, adding the acid cautiously, and heating until effervescence has ceased and solution is complete. The acetate of calcium may be made by dissolving the same weight of carbonate of calcium (marble dust) as that called for in the formula (or one-half that quantity of caustic lime), and treating it in the same manner. Add the two solutions together, dilute the volume to be required amount by the addition of water, and then to each gallon of the solution add a fluid ounce of free acetic acid, as prescribed. (Potts' solution.)

4.—Sulphate of nickel and ammonium, 10 parts; sulphate of ammonium, 4 parts; citric acid, 1 part; water, 200 parts.

The solution is made with the aid of heat, and, when cool, small fragments of carbonate of ammonium should be added until the bath is neutral to test paper.

5.—Sulphate of nickel, 6 parts; citrate of nickel, 3 parts; phosphate of nickel, 3 parts; benzoic acid, 1½ parts; water, 200 parts.

6.—Phosphate of nickel, 10 parts; citrate of nickel, 6 parts; pyrophosphate of sodium, 10½ parts; bisulphite of sodium, 1½ parts; citric acid, 3 parts; aqua ammonia, 15 parts; water, 400 parts.

7.—Sulphate of nickel, 6 parts; aqua ammonia, 3 parts; water, 100 parts.

When the nickel is dissolved add aqua ammonia, 20 parts.

This bath is similar to that recommended by Prof. Boettger; it is said to be well suited for the purposes of amateurs, inasmuch as it gives good results with a platinum anode. It is worked at a temperature of 100° F., with a moderate current. It requires renewal from time to time, as it becomes impoverished in nickel, by addition of fresh nickel salt; it must also be kept alkaline by the occasional addition of ammonia.

8.—Renickeling Old Work.—When goods which have been nickelplated require to be renickeled, it is always better to remove the old coating by means of a stripping solution, as nickel will not adhere to a coating of the same metal. A stripping bath may be composed as follows: Sulphuric acid, 16 lb.; nitric acid, 4 lb.; water, 2 qt. Add the sulphuric acid to the water (not the reverse, which is dangerous) gradually, and when the mixture has cooled down, add the nitric acid, and stir the mixture with a glass rod. When cold it is ready for use. Attach the articles to be stripped to a piece of stout brass or copper wire and place in the stripping liquid; they should be examined after a few moments. The operation of stripping should be conducted in the open air or in a fireplace with good draught. The articles should not be allowed to remain in the liquid one moment after the nickel has been dissolved from the surface, but be immediately removed and plunged into cold water.

9.—Tin, Britannia Metal, etc.—Sulphate of nickel and ammonium, 10 parts; sulphate of ammonium, 2 parts; water, 300 parts. The salts are to be dissolved in boiling water, and when cold the solution is ready for use. For nickeling cast and wrought iron and steel the following bath is recommended: Sulphate of nickel and ammonium, 10 parts; sulphate of ammonium, 1½ parts; water, 250 parts.

Silverplating

Simple Instructions for.—1.—For silverplating the bath consists of potassium

silver cyanide, prepared by precipitating solution of silver nitrate with potassium cyanide and redissolving the washed precipitate in excess of potassium cyanide solution—potassium cyanide, 12 oz.; water, 1 gal.; silver cyanide, about 1 troy oz. Filter and use in a porcelain or glazed vessel. For the whitening bath dissolve 1 lb. potassium cyanide in 1 gal. of water, add ¼ oz. troy of silver cyanide and filter the solution. The baths are provided with silver feeding plates for anodes proportioned in size to the surface of the work to be plated. These are connected with the positive pole of battery. The cleaned articles are connected by a copper wire with the zinc pole of the battery, dipped for a minute or two in the whitening bath, and when uniformly coated with a white film of silver, transferred to the plating bath, under similar conditions. 3 or 4 Smee cells with plates 10 x 4 in. will generally suffice for the plating bath, and 4 or 5 similar cells for the whitening bath; twenty to thirty minutes in the plating bath is usually sufficient to plate the work properly. Articles of copper, brass or German silver to be plated should first be cleaned by boiling them for a few minutes in strong potash water to free them from traces of oil or grease, and, after rinsing, in dilute nitric acid to remove any oxide and again thoroughly rinsed. It must not be touched by the hand after cleaning. Just before putting the work into the bath, dip it momentarily in strong nitric or a mixture of equal parts nitric and sulphuric acids and rinse quickly. After this treatment it is sometimes dipped for a moment in dilute aqueous mercurous nitrate solution and rinsed again. This has the effect of coating the clean metal with a film of mercury, which secures a perfect adhesion of the deposited silver.

2.—The Bath.—Water (soft), 1 gal.; cyanide of potassium (pure), 8 oz.; nitrate of silver, 5¼ oz.

Dissolve the nitrate of silver in a sufficient quantity of pure water (soft), and add to it gradually, with constant stirring, hydrocyanic (prussic) acid until all the silver has been precipitated as cyanide, which may be known by the formation of no cloud in a portion of the clear liquid when a drop of the acid is added to it. Avoid adding an excess of the acid. Throw the precipitate upon a fine cotton cloth filter, and as the liquid runs through wash the precipitate on the cloth several times with pure water. Dissolve the cyanide of potassium in the water, and stir in the cyanide of silver carefully removed from the cloth. If it does not dissolve in the liquid entirely, add more cyanide of potassium until it does, stirring continually. Let the impurities settle, and the bath is ready for use. Many electroplaters use a preliminary for silver "whitening" bath, which is the same composition, but contains less silver, more cyanide, and is worked with a somewhat stronger current.

The cleaned article in some cases is first dipped for a few moments in a solution of nitrate of mercury, 1 oz. in 1 gal. of water, and then in the whitening bath for a few minutes, and after brushing is transferred to the silver bath proper.

The vessels containing the cold bath are sufficiently high to allow about 4 in. of liquid above the immersed objects, whose distance from the bottom and sides should be nearly the same to give a regular deposit of metal at both ends of the object.

The upper ledge of the trough carries two brass rods all around, which do not touch one another, one above the other, so that other metallic rods placed transversely will rest upon the higher or lower series of rods only. The upper rods are connected with the zinc, the lower with the carbon or copper end of the battery, or with the corresponding poles of the dynamo-electric machine. The transverse rods resting upon the lower set support the silver anodes; those resting on the upper set, the work. The work suspended from an upper transverse is placed so as to face two anodes suspended from two lower transverse rods.

As the lower layers of the bath are apt to become denser (richer) than the upper, it is often necessary to reverse the articles during the operation to obtain a perfectly uniform thickness of deposit. For the same purpose small articles should be kept in motion as much as possible.

The deposit is finer and denser if obtained with a weak battery and long exposure than if a strong current is employed. A sufficient quantity of silver may be deposited in three or four hours, but it will be of much finer quality and more easily burnished if the work is left in the bath for twelve or fifteen hours with a few cells of batery.

When the articles especially coppered iron, etc., have acquired a coherent film of silver, they are sometimes removed from the bath, and thoroughly scratch-brushed, cleansed in alcohol, or preferably in a hot silvering bath, thence again

passed through the mercurial solution and finished in the cold plating bath.

The first scratch-brushing ,which is not always necessary, obviates the tendency of certain alloys to assume a crystalline appearance and corrects the imperfections of the cleansing in process.

Should the anodes become black during the passage of the current, the solution contains too little cyanide. In this the deposit is adherent, but too slow; and the bath loses more silver than it can gain from the anodes.

If the anodes remain white during the passage of the current, the bath contains an excess of cyanide, and the deposit does not properly adhere; correct by adding cyanide of silver until it dissolves with difficulty.

When in good working order, the anodes present a gray appearance while the current is passing, becoming white when circuit is broken.

The specific gravity of the bath may vary from 5° to 15° Baumé's hydrometer and still furnish good results.

Electro-silvering baths do not generally work so well when freshly prepared. If properly used and cared for, they improve by age. At first the deposit is often granulated bluish or yellowish.

It is customary to mix portions of an old bath with a freshly prepared one. Some platers introduce small quantities of ammonia instead to age the liquid.

Bisulphide of carbon in small quantities imparts a bright luster to plated articles. 1 oz. of the bisulphide is put into a pint bottle filled with a strong solution of the cyanide of potassium and silver, briskly shaken, and a few drops of this liquid poured into the bath occasionally until the work appears sufficiently bright. An excess of bisulphide must, however, be avoided, as it will spoil the bath.

What has been said about the arrangement of battery in articles of nickel and brass plating will also apply here.

3.—Deposits.—For electro-silverplating the double salt of silver and potassium cyanide is almost universally employed. The baths are used either hot or cold. The latter method is generally adopted for articles which require great solidity. The hot process is used for small articles, and is preferable for steel, iron, zinc, lead and tin, which have been previously electro-coppered. The hot baths are generally kept in enameled cast-iron kettles, and the articles are either suspended or moved constantly about in them. A somewhat energetic current is needed, especially when the articles are moved about in order to operate rapidly. A gray or black deposit indicates too strong a current, and when the surface becomes covered with bubbles of gas the same thing is indicated. The anodes are plates of silver or heavy silver foil. The wooden tanks for the cold baths are similar to those used in plating with copper and nickel, but should be very thoroughly coated on the inside with gutta percha.

Tin

1.—The following is one of the best solutions of plating with tin by the battery process: Potassium pyrophosphate, 12 oz.; protochloride of tin, 4½ oz.; water, 20 oz.

The anode or feeding plate used in this bath consists of pure Banca tin. This plate is joined to the positive (copper or carbon) pole of the battery, while the work is suspended from a wire connected with the negative (zinc) pole. A moderately strong battery is required, and the work is finished by scratch-brushing.

2.—In Weigler's process a bath is prepared by passing washed chlorine gas into a concentrated aqueous solution of stannous chloride to saturation, and expelling excess of gas by warming the solution, which is then diluted with about ten volumes of water and filtered, if necessary. The articles to be plated are pickled in dilute sulphuric acid, and polished with fine sand and scratch-brush, rinsed in water, loosely armed with zinc wire or tape, and immersed in the bath for ten or fifteen minutes at ordinary temperatures. The coating is finished with the scratch-brush and whiting.

By this process iron—cast or wrought—steel, copper, brass, and lead can be tinned without a separate battery. The only disadvantage of the process is that the bath soon becomes clogged up with zinc chloride, and the tin salt must be frequently renewed.

Zinc

Electro-deposition of.—For the electro-deposition of zinc solutions of the sulphate, ammonia sulphate, chloride and ammonia chloride may be employed, as also alkaline solutions, prepared by dissolving zinc oxide or carbonate in a solution of cyanide of potassium or caustic potassium; the deposit from either of these alkaline solutions is generally of very good quality, and if too strong a current be not employed the deposited metal is usually very tough.

COATING OF METALS BY OTHER PROCESSES

COPPER DEPOSIT BY DIPPING

This is seldom practiced except upon iron, as deposits thus obtained are gen-

erally wanting in lasting qualities, since, from the thinness of the coating, the iron is but imperfectly protected from atmospheric influences. If the iron is dipped in a solution of: Sulphate of copper, 3½ oz.; sulphuric acid, 3½ oz.; water, 1 to 2 gal.; it becomes covered with a coating of pure copper, having a certain adhesion; but should it remain there a few minutes, the deposit becomes thick and muddy, and does not stand any rubbing. Small articles, such as pins, hooks and nails, are thus coppered by tumbling them for a few moments in sand, bran, or sawdust impregnated with the above solution, diluted with three or four volumes of water.

GOLD

The metal employed for gilding is usually brass or a mixture of brass and copper. The following alloys have been recommended:

a.—Copper, 6 parts; brass, 1 part.

b.—Copper, 4 parts; Bristol brass, 1 part.

c.—Copper, 13 parts; old Bristol brass, 3 parts; tin, 14 parts.

1.—Mixtures employed in gilding by fire or by the wet processes.

Red Ormolu.—Potash alum, nitrate of potash, 30 parts of each; sulphate of zinc, 8 parts; common salt, 3 parts; red ocher, 28 parts; sulphate of iron, 1 part. Add to it a small proportion of annatto, madder, cochineal, or other coloring matter, ground in water or in weak vinegar.

Yellow Ormolu.—Red ocher, 17 parts; potash alum, 50 parts; sulphate of zinc, 10 parts; common salt, 3 parts; nitrate of potash, 20 parts.

2.—The following gilding solution will deposit a smooth and brilliant layer of gold on silver, brass, copper, etc.:

Gold chloride, 20 parts; potassium cyanide, 60 parts; potassium bitartrate, 5 parts; prepared chalk, 100 parts; water, distilled, 100 parts.

Dissolve the gold chloride in a portion of the water and the potassium salts in the remainder. Mix the solutions and stir in the prepared chalk. The articles to be gilded should be rendered free from grease, oxidation, etc., and the mixture applied with a woolen rag and rubbed well on.

Brass and Copper

1.—The following formula has been adopted for water gilding, as it is termed. Fine gold, 6¼ dwts. Convert the gold into chloride and dissolve in 1 qt. of distilled water, then add 1 lb. bicarbonate of potassium and boil the mixture for two hours. Immerse the articles to be gilded in the warm solution for a few seconds, up to one minute, according to the activity of the bath.

2.—Another method of gilding brass and copper articles, by simple immersion, is to first dip them in a solution of protonitrate of mercury (made by dissolving quicksilver in nitric acid and diluting with water) and then dipping them into the gilding liquid. It is said that copper may be gilded so perfectly by this method as to resist for some time the corrosive action of strong acids. During the action which takes place, the film of mercury, which is electro-positive to the gold, dissolves in the auriferous solution, and a film of gold is deposited in its place.

Bronze, etc.

Small articles may be gilded by immersing them in the following solution, which must be used at nearly boiling heat. Caustic potash, 180 parts; carbonate of potash, 20 parts; cyanide of potassium, 9 parts; water, 1,000 parts. Rather more than 1½ parts chloride of gold is to be dissolved in the water, when the other substances are to be added and the whole boiled together. The solution must be strengthened from time to time by the addition of chloride of gold, and also after being worked four or five times, by the addition of the other salts in the proportions given. This bath is recommended chiefly for gilding economically small articles of cheap jewelry, and for giving a preliminary coating of gold to large articles, which are to receive a stronger coating.

Mercury Gilding

Preparation of the Amalgam.—To prepare the amalgam of gold for the purpose of mercury gilding, weigh a quantity of fine or standard gold and put in a crucible and heat to dull redness. The requisite proportion of mercury, 8 parts to 1 part of gold, is now added, and the mixture is stirred with a slightly crooked iron rod, the heat being kept up until the gold is entirely dissolved by the mercury. Pour the amalgam into a small dish about 3 parts filled with water and work about with the fingers under the water to squeeze out as much of the excess of mercury as possible. To facilitate this, the dish is slightly inclined to allow the superfluous mercury to flow from the mass, which soon acquires a pasty condition capable of receiving the impression of the fingers. Afterward squeeze the amalgam in a chamois leather bag, by which a further quantity of mercury is

liberated; the amalgam which remains after this final treatment consists of about 33 parts of mercury and 57 parts of gold in 100 parts. The mercury which is pressed through the bag retains a good deal of gold, and is employed in preparing fresh batches of amalgam. It is important that the mercury employed should be pure.

The Mercurial Solution.—To apply the amalgam a solution of nitrate of mercury is employed, which is prepared by dissolving in a glass flask 100 parts of mercury in 110 parts of nitric acid, of sp. gr., 1.33, gentle heat being employed to assist the chemical action. The red fumes which are given off must be allowed to escape into the chimney, since they are highly deleterious when inhaled. When the mercury is all dissolved the solution is to be diluted with about 25 times its weight of distilled water and bottled for use.

Applying the Amalgam.—The pasty amalgam is spread with the blade of a knife upon a hard, flat stone; the article, after being well cleaned and scratch-brushed, is treated in the following way: Take a small scratch brush of nitrate of mercury, then draw over the amalgam; pass the brush carefully over the surface to be gilded, repeatedly dipping the brush in the mercurial solution, and drawing it over the amalgam, until the entire surface is uniformly and sufficiently coated. Then rinse the article well and dry. The next operation is the evaporation of the mercury. For this purpose a charcoal fire, resting upon a cast iron plate, has been generally adopted, a simple hood of sheet iron being the only means of protection from the injurious effects of the mercurial vapors. When the amalgamated article is rinsed and dried, it is exposed to the glowing charcoal, turned about and heated by degrees to the proper point; then it is withdrawn from the fire by means of long pincers or tongs. The article is then taken in the left hand, which should be protected with a leather glove, turned over the fire in every direction, and while the mercury is volatilizing the article should be struck with a long-haired brush to equalize the amalgam coating and force it upon such parts as may appear to require it. When the mercury has become entirely volatilized the gilding has a dull, greenish yellow color. If any bare places are apparent they are touched up with amalgam and the article again submitted to the fire, care being taken to expel the mercury gradually. The article is then well scratch-brushed; when it is of a pale, greenish color, heat it again to expel any remaining mercury, when it acquires the orange yellow of fine gold. If required to be bright it is burnished in the ordinary way.

Steel

Gold leaf, chlorhydric acid, nitric acid, sulphuric ether.

Mix the two acids in the proportion of one part of nitric acid and three parts of chlorhydric acid; dissolve the gold leaf in it and evaporate till dry. The residue is to be dissolved in the smallest quantity of water possible. Then a volume of ether equal to three times the quantity of water is to be added. The liquor is to be shaken in a closely stoppered bottle until the layer of ether is colored yellow, and the water has lost all its color.

To employ this solution, immerse in it the steel object, previously polished. The surface will be immediately gilded. An imitation of damaskeen work may be obtained. It is sufficient to apply a varnish of wax to the parts before they are covered by the gilding.

NICKELING

Nickeling may be performed on all metals, cold, by means of nickelene by the Mitressey process, recently introduced in France, and any desired thickness deposited. It is said to be more solid than nickel.

First Bath.—Clean the objects and take 5 kgm. of American potash per 25 liters of water. If the pieces are quite rusted, take 2 liters of chlorhydric acid per 1 liter of water. The bath is employed cold.

Second Bath.—Put 250 grammes of sulphate of copper in 25 liters of water. After dissolution add a few drops of sulphuric acid, drop by drop, stirring the liquid with a wooden stick until it becomes as clear as spring water.

Take out the pieces thus cleaned and place them in what is called the copper bath, attaching to them leaves of zinc; they will assume a red tint. Then pass them into the nickeling bath, which is thus composed:

Cream of tartar, 20 grams; sal ammoniac, in powder, 10 grams; kitchen salt, 5 grams; oxychlorhydrate of tin, 20 grams; sulphate of nickel, single, 30 grams; sulphate of nickel, double, 50 grams.

Remove the pieces from the bath in a few minutes and rub them with fine sand on a moist rag. Brilliancy will thus be

obtained. To improve the appearance, apply a brass wire brush.

Brilliancy may be also imparted by means of a piece of buff glued on a wooden wheel and smeared with English red stuff. This will give a glazed appearance.

PLATINUM

In this new process, the metallic object is covered with a mixture of borate of lead, oxide of copper, and spirits of turpentine, and submitted to a temperature of from 250° to 330°. This deposit, upon melting, spreads in a uniform layer over the object. Then a second coat is laid on, consisting of borate of lead, oxide of copper, and oil of lavender. Next, by means of a brush, the object is covered with a solution of chloride of platinum, which is finally evaporated at a temperature of not more than 200°.

The platinum adheres firmly to the surface, and exhibits a brilliant aspect. If the deposit be made upon the first coat, the platinum will have a dead appearance. Platinizing in this way costs, it is said, about one-tenth the price of nickel plating.

Copper

The appearance of platinum may be given to copper by immersion in a bath composed of 1¾ pt. hydrochloric acid, 7½ oz. arsenic acid, and 1¼ oz. acetate of copper. The article must be cleaned before immersion, and left in the bath till it has the color of platinum.

Silver

Place some platinum in a small quantity of aqua regia or nitro-muriatic acid, and keep it in a warm place a few days; it will dissolve. As soon as it has dissolved, evaporate the liquid at a gentle heat until it is as thick as honey, so as to get rid of the excess of the nitric and muriatic acids. Add a little water, and it is ready for use. A dozen drops of this solution goes a long way in platinizing silver. The operation is performed in a small glass or beaker, covered with a watchglass to keep in the fumes, and placed in a little sand in a saucer, to equalize the heat.

SILVER

Silver is used to a great extent in plating other metals, to which it imparts not only its fine color, but also great resistance to outward influences.

There are a number of methods of silverplating, which may be distinguished: 1. Cold plating by rubbing. 2. Wet plating by means of boiling. 3. Mechanical plating by pressing or rolling. 4. Fire-silvering. 5. Contact plating. 6. Electroplating. The latter method is the one which at present is almost exclusively employed.

Cast Iron, To Silver

1.—To silver cast iron, 15 gr. nitrate of silver are dissolved in 250 gr. water, and 30 gr. cyanide of potassium are added; when the solution is complete, the liquid is poured into 700 gr. water wherein 15 gr. common salt have been previously dissolved. The cast iron intended to be silvered by this solution should, after having been well cleaned, be placed for a few minutes in a bath of nitric acid of 1.2 sp. gr. just before being placed in the silvering fluid.

2.—A new process for silvering articles of iron is thus described. The article is first plunged in a pickle of hot dilute hydrochloric acid, whence it is removed to a solution of mercury nitrate, and connected with the zinc pole of a Bunsen element, gas carbon or platinum serving as the other pole. It is rapidly covered with a layer of quicksilver, when it is removed, washed, and transferred to a silver bath and silvered. By heating to 300° C. (572° Fah.) the mercury is driven off, and the silver firmly fixed on the iron. To save silver, the wire can be first covered with a layer of tin. One part of cream of tartar is dissolved in 8 parts of boiling water, and 1 or more tin anodes are joined with the carbon pole of a Bunsen element. The zinc pole communicates with a well cleaned piece of copper, and the battery is made to act till enough tin has deposited on the copper, when this is taken out and the ironware put in its place. The wire thus covered with tin chemically pure, and silvered, is said to be much cheaper than any other silvered metals.

Cold Plating (See Rubbing)

Dead Luster

Mix 7 oz. white lead and 1 oz. white litharge, with linseed-oil varnish. Mix this mass with an oil varnish.

Desilvering

The following is a liquid which will dissolve silver without attacking copper, brass, or German silver, so as to remove the silver from silvered objects, plated ware, etc. It is a mixture of 1 part of nitric acid with 6 parts sulphuric, heated

in a water bath of 160° F., at which temperature it operates best.

Rubbing

Cold Plating.—If certain silver compounds are brought into contact with other metals, such as zinc, iron, or copper, they will be decomposed, with separation of metallic silver; and this is the basis of a method of plating which consists merely in rubbing on a composition with a cork. Such a coating is not very durable, and only suitable for objects which are not to be submitted to any hard wear, such as the scales of thermometers and barometers.

1.—One of the older formulas for cold plating gives the following mixture: Silver chloride, 3 parts; salt, 3 parts; washed chalk, 2 parts; potash, 6 parts.

This compound is applied to the metal with a piece of moistened leather or with a cork. The object must previously be made bright, and is to be finally polished, after rinsing.

The silver chloride is obtained by dissolving silver in nitric acid, and adding to the solution hydrochloric acid, as long as there is any heavy white precipitate, resembling flakes of freshly precipitated cheese. This precipitate is filtered off, washed with water until the water, tried with ammonia, is no longer colored blue, and then dried in a dark place and also kept in the dark. Silver chloride is decomposed by light, becoming purple and finally black.

2.—A fine even plating is produced by application of a paste consisting of 1 part of silver nitrate and 3 of potassium cyanide. This is to be rubbed on with a woolen rag, the object afterward washed, and rubbed bright with leather. It is best to wear gloves when doing this, as potassium cyanide is so very poisonous that if the smallest scratch on the hand is touched by it, dangerous or even fatal ulcers may be caused.

3.—Small objects, such as buttons, are easily silvered by rubbing with a composition consisting of 3 parts of silver chloride, 8 parts of tartar, and 1 of salt, made into a paste.

4.—In another method, 1 part of powdered silver, chemically prepared by precipitation of a silver solution with copper, is rubbed together, dry, with 2 parts of tartar and 2 of salt, the mixture is moistened with enough water to make a thin paste, and is rubbed on with the finger or with a compact, stiff brush. Bronze, copper, or brass objects will take, in this way, a very beautiful dull white silver coating.

5.—Amalgam of Silver and Tin.—Put into a mortar 2 parts of mercury, 1 of chemically precipitated silver powder, 1 of tinfoil, and rub until the metals are amalgamated, then mix with 6 parts of bone ash, and apply the compound with a moist rag to brass or copper; it can also be used for bronze, and gives a silvery coating, which is much finer and more durable than many kinds of wet plating.

6.—Brass.—The first essential is that the metal be chemically clean, which is best done by the use of dilute nitric acid, followed by a wash with clean water, and then with dilute aqua ammonia, drying in sawdust. If the metal be then rubbed with chloride of silver dissolved in water and then washed and again dried in sawdust, the result will be fine. It should, however, be immediately lacquered in order to preserve the surface.

7.—Imitation of Cold Silver Plating.—Rub together equal quantities of mercury, tin, and bismuth, until amalgamated, and add one and a half times as much washed chalk. This compound, applied to brass, gives a silvery coating, lustrous, but not very durable.

Wet Plating

Cold Method.—There are upon the market various fluids, called "silvering fluid," "eau argentine," etc., which impart to clean and bright metal objects, simply immersed in them, a brilliant but very thin silver coating. The following are given for these fluids:

1.—Silver carbonate, 1 part; sodium hyposulphite, 10 parts; water, 10 parts. The silver carbonate is obtained by pouring a soda solution into a solution of silver nitrate, the resulting precipitate to be washed and dried. Or it need not be dried, but simply put into a glass vessel with the crystals of sodium hyposulphite, where water is poured over it and the solution hastened by frequent stirring. The fluid is then poured off from the undissolved residue of the silver carbonate. The objects immersed in it are to be touched with a zinc rod.

2.—Dissolve 1 oz. crystals of silver nitrate in 12 oz. soft water, then dissolve in the water 2 oz. potassium cyanide. Shake the whole together and let it stand until it becomes clear. Have ready some half ounce vials and fill them half full of Paris white or fine whiting and then fill up the bottles with the liquid and it is ready for use. The silver coating is not as tenacious to the article as when electrolytically deposited. This is very poisonous, and

should be handled with great caution—if at all.

3.—Boettger's Plating Fluid for Brass, Copper, Iron, and Steel.—Silver hyposulphite, 2 parts; ammonium chloride, 1 part; water, 20 parts.

The silver hyposulphite is obtained by dissolving silver nitrate in water, adding ammonia until the resulting precipitate again dissolves, then adding a concentrated solution of sodium hyposulphite and also alcohol. The silver hyposulphite which will be precipitated is to be well washed and dried. The fluid must always be freshly prepared, since the silver hyposulphite, which can be preserved dry, soon decomposes in solution. Iron and steel can be plated with this fluid directly, without previous copperplating, and one advantage which it possesses is that it is free from the poisonous potassium cyanide.

4.—Brass.—Silver nitrate, 29 grams (29 parts); potassium cyanide, 120 grams (120 parts); washed chalk, 30 grams (30 parts); water, 1 l. (1,000 parts).

Hot Method.—Plating can be done by boiling with liquids whose composition is similar to those employed in cold plating. If, for instance, the objects to be silvered are put into a compound consisting of 6 parts of tartar, 6 of salt, and 1 of silver chloride, there will be obtained, after fifteen or twenty minutes' boiling, a beautiful and durable silver plating, which, however, is not very lustrous. If a brilliant luster is desired, the objects may be heated, on coming from the plating fluid, in a solution consisting of 3 parts of sodium hyposulphite in 32 of water, and 1 of sugar of lead in 16 of water. Black lead sulphide will be precipitated, and after ten or fifteen minutes' heating the objects will have a bright coating of silver. The heating temperature should be from 70° to 80° C.

TIN

Preparation for Tinning

To prepare tin for tinning brass, copper and iron.—Melt the metal in a crucible which has previously been slightly warmed; and at the moment the metal begins to set, and when it is very brittle, pound it up rapidly, and sift when cold to remove any large particles.

Processes

Perhaps the best and cheapest substitute for silver as a white coating for tableware, culinary vessels, and the innumerable articles of manufacture requiring such a coating, is pure tin. It does not compare favorably with silver in point of hardness or wearing qualities, but it costs very much less than silver, is readily applied, and easily kept clean and bright.

There are several methods in use by which small articles, wire, etc., of iron, copper, brass, zinc and composition, are tin plated. These are: 1. By contact with melted tin. 2. By tin amalgam. 3. By simple immersion. 4. By battery.

1.—Contact Process.—The contact process is that by which all sheet tin, or, more properly, tinned sheet iron, is produced. In tinning hollow ware on the inside, the metal is first thoroughly cleansed by pickling it in dilute sulphuric acid, and scouring it with fine sand. It is then heated over a fire to about the melting point of tin, sprinkled with powdered rosin, and partly filled with melted pure grain tin covered with rosin to prevent its oxidation. The vessel is then quickly turned and rolled about in every direction, so as to bring every part of the surface in contact with the molten metal. The greater part of the tin is then thrown out, and the surface rubbed over with a brush of tow to equalize the coating. The operation is repeated, if necessary. The vessels usually tinned in this manner are of copper and brass, but with a little care in cleansing and manipulating, iron can also be satisfactorily tinned in this manner. The vessels must be hot enough to keep the tin contained in them fused.

2.—Amalgam Process.—The amalgam process is not used so much as it was formerly. It consists in applying to the clean and dry metallic surface a film of a pasty amalgam of tin with mercury, and then exposing the surface to heat, which volatilizes the latter, leaving the tin adhering to the metal.

3.—Immersion Process.—The immersion process is best adapted to coating articles of brass or copper. When immersed in a hot solution of tin properly prepared the metal is precipitated upon their surfaces. One of the best solutions for this purpose is the following: Ammonia alum, 17¼ oz.; boiling water, 12½ oz.; protochloride of tin, 1 oz. The articles to be tinned, first thoroughly cleansed, are put into the hot solution until properly whitened.

4.—A better coating can be obtained by using the following bath, and placing the pieces in contact with a strip of clean zinc, also immersed: Bitartrate of potassium, 14 oz.; water (soft), 24 oz.;

protochloride of tin, 1 oz. It should be boiled for a few minutes before using.

Brass

Small articles of brass like hooks and eyes may be covered with a thin coating of tin by any of the following methods:

1.—Make a saturated solution of cream of tartar in boiling water; place the articles to be coated between sheets of tin, immerse in the liquid, and boil until a sufficient deposit has been obtained. The brass should be freshly cleansed by immersion in dilute acid and subsequent washing or otherwise, just before being submitted to the tinning operation. The articles after being coated are washed in water and brightened by being shaken with bran.

2.—Boil peroxide of tin with a strong, aqueous caustic potash solution, until the liquid is saturated with tin, and immerse the articles in this solution.

3.—Roseleur recommends the following method: Prepare a solution of chloride of tin in crystals, 6 parts; pyrophosphate of sodium, 60 parts; distilled water, 3,000 parts. Place the articles on perforated zinc strays, immerse in the solution, and boil, stirring the contents occasionally to change the points of contact. The zinc trays are to be scraped clean after each operation to insure perfect contact in the next.

Castings

1.—Cleanse the castings by pickling in dilute sulphuric acid (1 to 20 of water) and scouring with sand ıf necessary. Then boil them in concentrated aqueous solution of stannate of soda, with a quantity of granulated tin. To copper iron castings, clean the iron as above and tumble it for a few minutes in sawdust moistened with a solution of copper in two gallons of water made slightly acid with sulphuric acid. Wash immediately in hot water.

2.—To tin small castings, clean and boil them with scraps of block tin in a solution of cream of tartar.

Cold Process.—Take equal parts of quicksilver and block tin and melt them together. Mix also equal parts of muriatic acid and water. Apply the amalgam with a clean rag steeped in the acid mixture.

ZINC

1.—For galvanizing cast iron with zinc, first clean the castings thoroughly by immersing in a bath of 1 part muriatic acid, 2 parts water, for a few hours; wash thoroughly in hot water and scrub with brush and sand. Then dip in a solution of sal ammoniac and water, ½ lb. to the gal., hot. Dry quickly and dip in the zinc bath.

2.—To galvanize sheet-iron work, dip in a bath of muriatic acid 1 part, water 4 parts; leave the work in long enough to break up the scale; clean with brushes or scrapers so that the surfaces shall be free from scale or dirt. Then dip in a fresh bath of muriatic acid and water, 1 to 4, with about 1 oz. sal ammoniac to the gal. of solution. Then dry quickly and thoroughly in a hot oven or on hot plates of iron and dip in the zinc bath. Never dip if any moisture remains among laps or rivets, for an explosion will ensue. Heat the zinc so that it will have a clear shining surface. Sprinkle a little powdered sal ammoniac upon the surface to clear it. Skim away the dross.

3.—Clean all scale, rust and dirt or oil from the surface, and if oily, by boiling in caustic soda, and then remove scale and rust by a bath of hydrochloric acid and water. If necessary a little scrubbing with a metallic brush, and then thoroughly rinse in hot water and dry quickly. After drying immerse in a bath of melted zinc, at the same time sprinkle a little powdered sal ammoniac upon the surface of the melted zinc to clear it. Judgment is required as to length of time for the immersion and temperature of the melted zinc. Very small work immersed but a few seconds.

Iron

Electrolytic Method.—Perfectly bright iron, dipped in a solution of zinc vitriol, and exposed to a strong electrical current, becomes quickly coated over with pure zinc. The coating, however, is dull; to give the usual luster of zinc, the sheets are quickly heated to the melting point of zinc, cooled, and passed between smooth rollers.

Small Objects.—To galvanize small iron articles, such as chains, rings, hooks and nails, thereby protecting them from rust, they are first put into a vessel containing dilute sulphuric acid, in order to pickle them bright, then dried, and put into the melted zinc. The usual method is to lay the articles into a net or basket of strong wire, and to immerse this in the melted metal, shaking it around to make sure that all the pieces come in contact with the zinc. After remaining two or three minutes in the zinc bath, they are removed and thrown into a little flame-oven, covered with powdered coal and brought to a red heat. The excess of zinc is hereby melted off, and collects

in the lowest parts of the bottom of the oven. The articles are then drawn with rakes into the higher portions of the oven, moved around until the zinc coating has hardened, and the adhering coal powder is then rubbed off.

The zinc coatings on small articles are more durable if the objects are first lightly copperplated before galvanizing. The simplest way of doing this is to put them, after pickling, into a trough and pour over them a solution of one part of blue vitriol to ten of water; after having remained a few moments in contact with the fluid, they are removed, rinsed and thrown into the zinc bath. The thickness of the zinc coating varies according to the time during which the objects are left in contact with the fluid zinc; experiments have shown that in the case of galvanized sheet iron, the thickness of the layer varies from 0.006 to 0.043 millimeter, which corresponds to 45-300 gram of zinc per square meter of surface.

CHAPTER VI.

GLASS

Bending Glass Tubes

1.—Place the part where the curve is required in the flame of a spirit lamp or in an ordinary gas flame (the whole of the surface must be equally heated); when the glass begins to soften, a gentle pressure by the hands will give the necessary bend.

2.—Fill them with sand; this is necessary in three cases: when the tube is very wide, when the glass is thin, and when the curve is to be of a very long radius; in the latter case, the tube, filled with sand, is best heated over a large furnace with burning charcoal.

Blowing Glass

The technique of glass blowing is so comprehensive that it cannot be described in sufficient detail in a book of formulas. There are, however, two excellent little books on the subject which are profusely illustrated, and which are very inexpensive. To them the reader is referred.

Breaking (See also **Cutting**)

1.—Easy method of breaking glass to any required form. Make a small notch, by means of a file, on the edge of a piece of glass, then make the end of a tobacco pipe, or a rod of iron of about the same size, red hot in the fire; apply the hot iron to the notch, and draw it slowly along the surface of the glass in any direction you please; a crack will be made in the glass, and will follow the direction of the iron.

2.—Round glass bottles and flasks may be cut in the middle by wrapping around them a worsted thread dipped in spirits of turpentine, and setting it on fire when fastened on the glass.

3.—In breaking a glass tube—*e.g.*, a combustion tube—a small scratch is made with a file at the required place. At each side of this scratch, and about 1 to 2 mm. away from it, a small roll of wet blotting paper is laid around the tube. The free space between is then heated all around over a Bunsen burner, or, better still, over a small blowpipe flame. A clean and even fracture is thus obtained, exactly between the two rolls, without dropping water on the hot glass. The rolls are made by cutting two strips of filter paper sufficiently large to form rolls 1 to 2 mm. high and 2 to 4 cm. wide. The strips are folded once, lengthways, laid on the table, moistened, flattened out, and then wrapped on to the tube, so that the fold lies nearest the file scratch, and fold lies accurately upon fold in the successive layers. The thickness of the rolls, and their distance apart, has, of course, to be varied according to the diameter of the tubes. Equally good results are obtained with the thinnest test tubes, the thickest combustion tubes, beakers, flasks and glass bell jars. In those cases, where the sides are slanting, as, for instance, with funnels, an obvious alteration in the construction of the paper rolls need only be carried out.

Cutting Glass (See also **Bending, Breaking, Drilling** and **Boring**)

Cutting.—1.—To cut glass well a fine diamond should be used, and considerable skill is required in its use. The file and the red-hot poker are also efficient means of cutting glass, the crack following the hot iron.

2.—Bottles.—a.—This method consists in the use of what in German is called "sprengkohle," cracking cold. The "sprengkohle" is made of finely ground limewood charcoal. The coal powder is transformed by means of sufficient gum tragacanth and water into a dough or paste, out of which small cylinders of the size of a pencil are made by rolling between two small pieces of board. Such a cylinder of sprengkohle, ignited at one end, glows slowly. Such sprengkohle may be bought at stores for chemical and physical necessities. Now as for the use of the sprengkohle, it is as follows: Put a drop of water on the spot where the crack is to begin. Make a short incision with a three-edged file. Wipe the water away. Touch the incision with the glowing "sprengkohle," blowing on it if required. After a few seconds the glass will crack for a length of ¼ to 1 in. If now you move the sprengkohle slowly the crack follows it wherever you please.

3.—Holes, Large, To Cut.—Bore a hole in the center by means of a hard steel

drill moistened with turpentine; cut the circle with a good glazier's diamond, guided by a small piece of copper wire centered in the hole just bored, and by means of cuts radiating from the center to the circumference divide the circle into numerous small sectors. Then, with a small piece of metal, tap the glass on the posterior side gently, following each cut throughout its extent. When this has been properly done fasten a piece of putty over the area of the circle on the cut side of the glass, and, while holding the putty, tap the glass on the other side firmly in the center of the circle. Too much pressure on the diamond will cause it to scratch, without cutting the glass.

Carbon Points for Splitting Glass.—1.—Gum arabic, 10 dr.; water, 3 oz.; tragacanth, powdered, 4 dr.; hot water, 8 oz.; storax, 2 dr.; benzoin, 2 dr.; alcohol, 91°, 9 dr.; powdered charcoal, 3 to 3½ oz. Dissolve the gum arabic in the cold water and mix it with the paste made from the tragacanth and hot water. To the mucilage add the rosins, dissolved in the alcohol, and enough finely powdered charcoal to form a mass to be rolled into cylinders of suitable length, and about 4-10 of an in. in diameter. While rolling the sticks, powdered charcoal is employed to prevent adhesion. When thoroughly dry, the pencils are ready for use, and are managed as follows: One end is sharpened like a lead pencil, and ignited; then, the glass having been scratched with a diamond, the heated and glowing point of the pencil is carried close to the glass in the direction in which it is intended to split it.

2.—The following receipts produce a pencil burning more rapidly than the above: Gum tragacanth, 1 dr.; hot water, 10 dr.; acetate of lead, 3 dr.; finely powdered charcoal, 6 dr. Proceed as formerly.

3.—Sticks of willow or poplar, or any soft wood of about the thickness of a finger, are thoroughly dried, and immersed for about 7 days in a concentrated solution of sugar of lead. When dry, they are ready for use, and burn quite readily and evenly.

Drilling and Boring Glass

1.—In the Scientific American these directions are given: Make a solution of 1 oz. of camphor, 1½ oz. of spirits of turpentine and 3 dr. of ether. Keep the end of the drilling tool wet with this fluid. The sharp corner of a freshly broken point of a file is one of the best drilling tools for this purpose.

2.—To drill a ¼-in. hole in a glass shade, make a hole in a piece of wood or metal of the size that you desire to drill in the glass. Fasten it with beeswax upon the glass for a guide. A piece of brass or copper tubing, quite thin, is supplied with emery (No. 100) and water and twirled between the fingers or with a bowstring. This will cut a hole in a few minutes. You can feed the emery and water a little at a time through the tube.

3.—Can be done with a hard drill and spirits of turpentine—a tedious and uncertain process, and only for small holes. A diamond drill is much better and cheaper, if there are many holes to drill. If large holes are wanted, from ¼ to 1 in., or larger, prepare a piece of thin tubing, of brass or copper, of the required size of hole, of 1 or 2 in. in length, with small spindle and grooved pulley attached, something after the style of the watchmaker's bow drill. Fasten upon the plate of glass, at the point to be drilled, a ring of metal or wood for a guide to keep the tubular drill in its place until the cut is started sufficiently to steady the cutter. Lay the glass plate horizontally, and work the drill perpendicularly with the bow, using one hand to steady the uper end of the drill stock. Feed emery (about No. 90) and water into the open end of the tube as fast as required. In a very short time you will cut a disk out of the plate.

4.—For drilling holes in glass, a common steel drill, well made, and well tempered, the Glassware Review claims to be the best tool. The steel should be forged at a low temperature, so as to be sure not to burn it, and then tempered as hard as possible in a bath of salt water that has been well boiled. Such a drill will go through glass very rapidly if kept well moistened with turpentine in which some camphor has been dissolved. Dilute sulphuric acid is equally good, if not better. It is stated that at Berlin glass castings for pump barrels, etc., are drilled, planed and bored like iron ones, and in the same lathes and machines, by aid of sulphuric acid. A little practice with these different means will enable the operator to cut and work glass as easily as brass or iron.

5.—The following directions were contributed to Design and Work by an optician: First make a saturated solution of camphor in spirits of turpentine; then make a spear-shaped drill the size of the hole required; heat the drill to a white heat, and plunge into mercury, and it will then be very hard; sharpen on an oilstone, knock drill in a bradawl handle,

dip the end of drill into the above solution, and work it as if you were working it through wood. It is no use fixing the drill in a drillstock, because the motion all one way will not do. Keep the drill well moistened with the solution, and sharpen it when blunt. A file, dipped into the solution, will file the hole larger and will not get blunt.

Etching

In the opaque etching of glass it has hitherto been thought necessary to use certain expensive fluorine salts in the preparation of etching solutions. It has been discovered by A. Lainer that comparatively cheap etching can be prepared. In Dingler's Polytechnisches Journal, Lainer gives two recipes which obviate the use of the more expensive fluorine salts.

1.—Two solutions are first prepared: (a) Consisting of 10 grams of soda in 20 grams of warm water; (b) consisting of 10 grams of potassium carbonate in 20 grams of warm water. Solutions (a) and (b) are now mixed, and to the mixture is added 20 grams of concentrated hydrofluoric acid, and afterward a solution (c) consisting of 10 grams of potassium sulphate in 10 grams of water is added.

2.—This recipe contains the following ingredients: Water, 4 c.c.; potassium carbonate, 1 1-3 grams; dilute hydrofluoric acid, 0.5 c.c.; hydrochloric acid, 0 5 c.c.; potassium sulphate, 0.5 c.c. This mixture is treated with hydrofluoric acid and carbonate of potassium until it produces the required degree of opacity on being tried upon a piece of glass.

3.—But it appears that there is a still simpler process than either of these. It was invented by Herr Kampmann, of Vienna. In preparing an opaque etching fluid, Kampmann uses a wooden vessel, the iron fittings of which are protected from the corrosive action of the acid fumes by a layer of asphalted material. This vessel is filled to about one-fifth of its contents with strong hydrofluoric acid, which is then partially neutralized by cautiously and gradually adding some crystals of soda; more soda is added, and the mixture is stirred with a small wooden rod. The point at which the neutralization of the acid should cease is indicated by the mixture frothing and becoming sufficiently viscid to adhere to the stirring rod. It is, perhaps, hardly necessary to say that the acid fumes are highly injurious, and that this process should be carried on in the open air, in order to allow the vapor to pass rapidly away. The most hygienic and satisfactory process of all would be to carry on the operation in a draught cupboard. The contents of this wooden vessel now consist of sodium fluoride and the unneutralized hydrofluoric acid. This mixture is now transferred to a wooden tub, and diluted with from 5 to 10 times its volume of water, according to the degree of dilution that is desired. It is objectionable to use this mixture in a too highly concentrated condition, for then the etched surface of the glass is irregular, coarse-grained, and apparently strewn with tiny crystals; if, on the other hand, the dilution be too extreme, the etched surfaces will be transparent instead of opaque. Either of these two conditions of the etching fluid can easily be remedied; for, if it be too strong, water must be added; and if too weak, a small quantity of hydrofluoric acid, partially neutralized with soda, must be mixed in.

4.—A good recipe for preparing a small quantity of this etching fluid is the following: Commercial hydrofluoric acid 240 c.c.; powdered crystallized soda, 600 grams; water, 100 c.c. These etching fluids are best used by taking the following precautions: The glass is first thoroughly cleansed from all impurities, and is then provided with a rim of wax composed of the following ingredients: Beeswax, tallow, colophony and powdered asphalt, kneaded together. The rim prevents the acid from spreading over those parts of the surface which it is not desired to etch. The glass is now etched for a few minutes with an ordinary etching solution (H.F.—1: 10), which is then poured off, the surface being afterward washed with water and wiped as dry as posisble with a piece of sponge. The surface is now ready for the opaque etching fluid, which is poured on till it forms a thick layer. The operation is allowed to progress for an hour, when the liquid is poured away and the surface washed with water. Water is further allowed to stand on the glass until a thin film of silicate is observed to form; this film is then brushed off, and the surface finally cleansed with water, and the wax removed. By varying the action of this opaque etching fluid or paste, various degrees of opacity may be produced, and if the opacity be greater than that which is desired, the surface can be cleared to any extent by using the etching solution of hydrofluoric acid.

5.—Fancy work, with ornamental figures, lettering and monograms, are most easily and neatly cut into glass by the sandblast process. Lines and figures on

tubes, jars, etc., may be deeply etche by smearing the surface of the glass with beeswax, drawing the lines with a steel point, and exposing the glass to the fumes of hydrofluoric acid. This acid is obtained by putting powdered fluorspar into a tray made of sheet lead, and pouring sulphuric acid on it, after which the tray is slightly warmed. The proportions will, of course, vary with the purity of the materials used, fluorspar (except when in crystals) being generally mixed with a large quantity of other matter; but this point need not affect the success of the operation. Enough acid to make a thin paste with the powdered spar will be about right. Where a lead tray is not at hand, the powdered spar may be poured on the glass and the acid poured on it, and left for some time. As a general rule, the marks are opaque, but sometimes they are transparent. In this case, cut them deeply and fill up with black varnish, if they are required to be very plain, as in the case of graduated vessels. Liquid hydrofluoric acid has been recommended for etching, but is not suitable, as it leaves the surface on which it acts transparent. The agent which corrodes the glass is a gas which does not remain in the mixture of spar and acid, but passes off in the vapor. The following formula has been published under the title of "Etching Ink": Ammonium fluoride, 2 dr.; barium sulphate, 2 dr. Reduce to a fine powder in a mortar, then transfer to a lead dish, and make into a thin writing cream with hydrofluoric acid (some make use of fuming sulphuric acid). Use a piece of lead to stir the mixture. The "ink" may be put up in bottles coated with paraffine, which can be done by heating the bottle, pouring in some melted paraffine, and letting it flow all around. The writing is done with a quill, and in about half a minute the ink is washed off. Extreme caution must be observed in handling the acid, since, when brought in contact with the skin it produces dangerous sores, very difficult to heal. The vapor is also dangerously poisonous when inhaled.

6.—Mix in a lead flask 30 parts of ammonium fluoride, 15 parts of distilled water and 6 parts of pure sulphuric acid; warm to 40° C.—but not higher—and add, after cooling, 6 parts of strong hydrofluoric acid and 1 to 2 parts of gum arabic in solution. Close the flask with a well fitting lead stopper. For particularly delicate drawings the quantity of gum arabic should be increased. Steel pens or goose quills may be used.

7.—Sodium fluoride, 36 parts; potassium sulphate, 7 parts; distilled water, 500 parts. Mix.

8.—Zinc chloride, 14 parts; distilled water, 500 parts; acid hydrochloric, 65 parts. Mix. Dissolve in separate vessels, and mix the solutions only when required for use. Write with a clean quill pen, being careful not to get too much of the liquid on the pen, as there is danger of blotting. The writing or etching appears in the course of a half hour.

9.—Commonly used for etching glass tumblers: Sodium fluoride, 1 oz.; glacial acetic acid, 10 dr.; water, 25 oz. Dissolve the sodium fluoride in water and add the acetic acid. The article to be etched is first coated with etching varnish, which is scratched off where a pattern is desired, and then immersed in the solution. The fluid is sometimes applied by means of a rubber stamp.

10.—Ammonium fluoride, 10%; barium sulphate, 10%; hydrofluoric acid, fuming, enough. Use enough acid to decompose the ammonium fluoride.

11.—Ammonium fluoride, 10%; barium sulphate, 30%; water, enough. This is made into a semi-liquid mixture, and may be applied with a common pen.

12.—Sodium fluoride, 0.72%; potassium sulphate, 0.14%; water, 240%. Make, and add to the foregoing, another solution, consisting of zinc chloride, 0.28%; hydrochloric acid, 40%; water, 40%. At the end of half an hour the design should be sufficiently etched.

13.—Sandblasting Process.—The process here described consists in corroding glass by violently projecting sand upon its surface by means of a current of air or steam. The apparatus used is very simple. Well dried sand, contained in a cylindrical vessel, is allowed to flow in a continuous manner through a tube, whose length and inclination can be altered at will so as to regulate the fall of the sand. The tube conveying the current of air or steam terminates just above this spout, in a nozzle containing a series of fine holes. The sand, urged on by the jet, is thrown violently against the glass plate, or other body placed within its range, and thus exerts a corroding action. By varying the quantity of the sand, the volume and velocity of the current, as well as the diameter of the jet, more or less rapid effects are produced. In engraving on glass, very little pressure is needed, the current from the bellows of an enameler's lamp being quite sufficient. In this way the divisions on graduated tubes, the labels on bottles, etc..

can easily be engraved in laboratories with but little trouble. The portions of the glass which are to remain clear are covered with paper, or with an elastic varnish, these substances being sufficiently exempt from the corroding action of the sand.

Frosting Glass

1.—Rub over with a little bag of muslin filled with fine sand, powdered glass, or grindstone grit, and water. Some sand may be placed directly on the glass.

2.—Clean the windows thoroughly, and moisten with hydrofluoric acid. When frosted enough, wash thoroughly.

3.—Make a saturated solution of alum water, and wet the glass with the liquid. It is advisable to have the glass in a horizontal position, as the solution is not likely to drain off. The more slowly it is cooled the more perfect the crystals will be. If desired, the alum solution may be colored with cochineal, and, of course, the more solution used the thicker will be the crystals.

4.—Dissolve 2 tablespoonfuls of Epsom salts in 1 pt. of lager beer, and apply the brush.

5.—Sandarach, 18 dr.; mastic, 4 dr.; ether, 24 oz.; benzine, 16 to 18 oz. This mixture is to be painted on the glass.

6.—Frosted glass may be oranmented as follows: Choose some pretty pattern of lace curtains, lay it upon thin paper, and then with a pencil trace the outlines. After making as many layers as you require patterns, cut out the designs at one time through the several layers of paper with sharp scissors. Fasten the pattern with tacks to the frame around each pane of glass you wish to decorate. Tie up a piece of putty in a piece of thin muslin, leaving enough of the latter to hold instead of a handle. With this dabble all over the part of the glass which the pattern leaves bare. When the pattern on the glass is dry remove the paper and varnish the glass.

7.—Dip a piece of flat marble into glass-cutter's sharp sand moistened with water; rub over the glass, dipping frequently in sand and water. If the frosting is required very fine, finish off with emery and water.

8.—As a temporary frosting for windows, mix together a strong, hot solution of epsom salt and a clear solution of gum arabic; apply warm.

9.—Use a strong solution of sodium sulphate, warm, and when cool wash with gum water.

10.—Daub the glass with a lump of glazier's putty, carefully and uniformly, until the surface is equally covered. This is an excellent imitation of ground glass, and is not disturbed by rain or damp.

Grinding Glass Tube

It is very easy to true the interior of glass tube by chucking same (cemented hot by pitch) into a true hole bored by a slide rest in a wooden carver's chuck, attached to a lathe face plate. Then grind out with fine emery the interior by sliding a rod of steel one-third less diameter, fixed firmly and truly in the slide rest tool holder, so as to just bear upon the descending side of the inner tube, as the former moves in and out, and is constantly supplied with plenty of water and fresh emery. Polish by wrapping a few thicknesses of alpaca or linen round the steel, and use finely washed rouge. This is the only way to get a perfectly true barrel.

Ground Glass

Lainer recommends the following process in the Chemiker Zeitung: Mix 240 c. cm. of commercial hydrofluoric acid of 1.258 specific gravity with 600 grams of pulverized soda crystals, then dilute with 1000 c. c.m. of water. After standing for some time a sediment is formed, and over it a clear solution. The thoroughly cleaned glass pane is produced with a wax edge (prepared by kneading yellow wax with tallow, rosin and asphalt powder) and pre-etched with common hydrofluoric acid (1: 10) for some minutes to obtain an absolutely clean glass surface. Then wash with water and wipe the plate with a clean, soft sponge until the surface is only slightly moist. Stir up the paste of the etching acid, and pour the mass ½ to 1 cm. high upon the pane. With this mixture a nice normal deadening is obtained after one hour. If the acid is old, having been used often, it may be made to act longer upon the plate of glass. The liquid is poured back into the vat, and the glass is rinsed off with water. Then the water is allowed to remain upon the pane until a skin, formed from the surface of the glass, can be removed with the finger or a brush. The strong deadening obtained by this method can be fixed to any desired degree of transparency by etching with hydrofluoric acid.

Powdering

Powdered glass is frequently used instead of paper, cloth, cotton or sand for filtering varnishes, acids, etc. It is not soluble or corrodible. Sand, if purely silicious, would be better, but such sand is difficult to get; it too often contains

matters which are easily corroded or dissolved. Powdered glass, when glued to paper, is also used for polishing wood and other materials. It cuts rapidly and cleanly, and is better than sand for most purposes. Glass is easily pulverized after being heated red hot and plunged into cold water. It cracks in every direction, becomes hard and brittle, and breaks with keenly cutting edges. After being pounded in a mortar it may be divided into powders of different degrees of fineness by being sifted through lawn sieves.

Silvering Glass

1.—Ordinary water must never be used in silvering; it must always be distilled water. (a) Reducing Solution: In 12 oz. of water dissolve 12 gr. of Rochelle salts, and boil; while boiling, add 16 gr. of nitrate of silver dissolved in 1 oz. of water, and continue the boiling for 10 minutes more; then add water to make 12 oz. (b) Silvering solution: Dissolve 1 oz. of nitrate of silver in 10 oz. of water, then add liquid ammonia until the brown precipitate is nearly, but not quite, all dissolved; then add 1 oz. of alcohol, and sufficient water to make 12 oz. To silver: Take equal parts of (a) and (b), mix thoroughly, and lay the glass, face down, on top of the mixture while wet, after it has been carefully cleaned with soda and well rinsed with clean water. Distilled water should be used for making the solutions. About 2 dr. of each will silver a plate 2 in. square. The dish in which the silvering is done should be only a little larger than the plate. The solution should stand and settle for 2 or 3 days before being used, and will keep good a long time.

2.—(a) Nitrate of silver, 1 oz.; water, 10 oz. (b) Caustic potash, 1 oz.; water, 10 oz. (c) Glucose, ½ oz.; water, 10 oz. The above quantities are those estimated for 250 sq. in. of surface; add ammonia to solution (a) till the turbidity first produced is just cleared; now add (b), and again ammonia to clear; then a little solution, drop by drop, till the appearance is decidedly turbid again; then add (c), and apply to the clean glass surface. A film was obtained in 43 minutes at a temperature of 56° F.

3.—First take 80 gr. of nitrate of silver (either lunar caustic or the crystallized salt), and dissolve it in 10 oz. of water, preferably distilled or rain water. To this add 2 oz. of alcohol and 2 oz. of aqua ammonia. The ammonia is added to the solution, drop by drop, until the precipitate at first formed is dissolved. The solution is then allowed to settle for 3 or 4 hours, when it is ready for use, and forms solution No. 1. Then take 6 oz. of water and dissolve it in 24 grams of nitrate of silver, and add to the same 30 grams of arsenite or tartrate of copper, and then add, drop by drop, sufficient aqua ammonia to dissolve the precipitate of oxide of silver at first formed, and the arsenite or tartrate of copper, after which add 2 oz. of alcohol. Then make a separate solution of 48 grams of potassa in 16 oz. of water. This last mentioned solution is brought to a boiling temperature in an evaporating dish, after which the solution of nitrate of silver and arsenite or tartrate of copper is added, drop by drop, to the boiling solution of potassa, and the boiling is continued for about an hour, or until a white film collects on the surface, after which it is allowed to cool and filter, when it is ready for use, and forms solution No. 2. In depositing the alloy upon the glass, take a suitable quantity of filtered water, preferably rain or distilled water, and add to it equal parts of solutions Nos. 1 and 2, and mix the whole thoroughly, and apply this solution in any convenient manner to the glass to be coated, and the deposition immediately commences, and is allowed to continue, say, for about 10 minutes, until the metal in solution is entirely exhausted, when the glass will be covered with a coating of the alloy, having a brilliant reflecting surface adjoining the glass. In order to increase the durability of the coating it is preferable to deposit a second coating upon the first, which is done by repeating the operation before the first coating is dry, and after the coating is completed, generally cover the whole with a heavy coat of asphaltum varnish, although this is not absolutely necessary, as the metallic alloy is sufficiently hard to stand ordinary wear without it. By the above described process an alloy having all the qualities of hardness and durability of the ordinary alloys of copper and silver is deposited upon the glass, and the degree of hardness may be varied or modified by varying the proportions of the different ingredients employed. Other salts of copper besides the arsenite or tartrate may be employed in conjunction with the nitrate of silver.

4.—Silvering solution: Dissolve 48 gr. of silver nitrate in 1 oz. of distilled water, and to the solution add ammonia water until the prècipitate at first thrown down by it is nearly, but not quite, redissolved. Let stand for an hour or two, then filter, and to the filtrate add sufficient distilled water to make 12 fl.oz. Reducing solu-

tion: In a flask of sufficient capacity dissolve 12 gr. of sodium and potassium tartrate (Rochelle salt) in 1 oz. of distilled water. Bring to a boil, and while boiling add 2 gr. of silver nitrate dissolved in 1 dr. of distilled water. Let boil for 3 or 4 minutes, then remove from the fire; let cool down, and after letting stand a few minutes filter through paper. To the filtrate add sufficient distilled water to make, as before, 12 fl.oz. To use: Make the glass to be silvered chemically clean on the side on which the silver is to be deposited. To effect this, cleanse first with sulphuric or nitric acid, rinse in running water, and then flood with liquor potassae. If necessary, to get rid of grease, repeat these processes, rinse in running water, and finally in alcohol. Be careful not to let your fingers come in contact with the surface after cleansing, but handle the plate either with clean wooden forceps or in such manner that nothing comes in contact with the cleaned surface. To silver, equal parts of the fluids are necessary. As the deposition of the metal goes on from every direction at once, but is strongest and best at the top, smaller mirrors are silvered by suspending the glass, cleaned surface downward, over a vessel having the same superficial area as the glass, set perfectly level, and filled with the mixed liquid. The surface of the glass should exactly touch that of the liquid at all points, and care should be taken that no bubbles or air spaces are left between the surfaces. In warm weather, all that is necessary is to place the vessel and glass where the direct sunlight (or a strong diffused light) can reach it; but in cold weather the apparatus should be kept at a temperature of from 90 to 110° F. The liquid at first becomes intensely black, but clears up as the reduction progresses. As soon as it becomes somewhat clear the process should be stopped, the glass removed and rinsed under running water, and allowed to dry spontaneously. The silvered surface should subsequently be varnished with a strong solution of shellac into which some thickening powder (such as English red) has been stirred. While the silvering and reducing liquids are the same, larger mirrors are treated very differently.

5.—Dissolve 120 gr. of silver nitrate in 2 oz. of distilled water, and pour this solution quickly into a boiling solution of 96 gr. of Rochelle salt in about 2 oz. of water. When cool, filter, and make up to 24 fl.oz. with distilled water. Now make a separate solution of 120 gr. of silver nitrate in 2 oz. of distilled water, and add ammonia until the precipitate is nearly redissolved. Make up to 24 fl.oz. with distilled water. For use, mix equal quantities of these two solutions just before the silvering is to be done.

6.—Dissolve 96 gr. of silver nitrate in 2 oz. of distilled water, and add ammonia until the precipitate is nearly dissolved; filter, and make up to 24 fl. dr. with distilled water. Now make a separate solution of 42 gr. of Rochelle salt in 2 oz. of distilled water; boil this, and while boiling add 4 gr. of nitrate of silver, previously dissolved in 2 dr. of water. When cool, filter, and make up to 24 fl.dr. For use, mix equal quantities of the two solutions just before the silvering is to be done.

7.—Pure silver nitrate, 10 gr. to 1 oz. of distilled water; add carefully, drop by drop, strong ammonia, until the brown precipitate is redissolved. When adding the ammonia keep stirring with a glass rod. In another bottle make a solution of 10 gr. of pure crystallized Rochelle salt to 1 oz. of distilled water; then, when you have all ready, pour on sufficient to cover all the glass, using two-thirds of the silver solution and one-third of the Rochelle salt. The mirror can be prepared well by cleansing it with a little wet rouge and polishing dry with a washleather; then warm the glass before the fire, or by letting it lie in the sun, to about 70 or 80° F. Pour on the solution as described above, and let it stand in the warm sunshine ½ to 1 hour. When silvered, pour on it some clean soft or distilled water, and while still wet wipe it very gently all over with a little soft wadding, wet; this will take off all the roughness, so that it will take but little rubbing with the rouge leather to polish it. When perfectly dry it is easily rubbed up to an exquisite polish.

8.—Place a sheet of glass, previously washed clean with water, on a table, and rub the whole surface with a rubber of cotton, wetted with distilled water, and afterward with a solution of Rochelle salt in distilled water, 1 part of salt to 200 parts of water. Then take a solution, previously prepared by adding silver nitrate to ammonia of commerce, the silver being gradually added until a brown precipitate commences to be produced; the solution is then filtered. For each square yard of glass take as much of the above solution as contains 20 grams (about 309 gr.) of silver, and to this add as much of a solution of Rochelle salt as contains 14 grams of salt, and the strength of the latter solution should be so adjusted to that of the silver solu-

tion that the total weight of the mixture above mentioned may be 60 grams. In a minute or two after the mixture is made it becomes turbid, and it is then immediately to be poured over the surface of the glass, which has previously been placed on a perfectly horizontal table, but the plate is blocked up at one end to give it an inclination about 1 in 40; the liquid is then poured on in such a manner as to distribute it over the whole surface without allowing it to escape at the edges. When this is effected the plate is placed in a horizontal position at a temperature of about 68° F. The silver will begin to appear in about 2 minutes, and in 20 to 30 minutes sufficient silver will be deposited. The mixture is then poured off the plate, and the silver it contains is afterward recovered. The surface is then washed four or five times, and the plate is set up to dry. When dry, the plate is varnished by pouring over it a varnish composed of gum dammar, 20 parts; asphalt of bitumen, 5 parts; gutta percha, 5 parts; benzine, 75 parts. This varnish will set hard on the glass, and the plate is then ready for use.

Varnish for Back of Silvered Mirrors. —Dammar gum, 20 parts; asphalt, 3 parts; gutta-percha, 5 parts; benzol, 75 parts. Mix and dissolve.

To use this varnish pour it over the silvered surface and move the plate back and forth until it is distributed evenly over the face.

Stoppers

Fitting.—1.—To fit a stopper to a bottle that has not been ground, use emery or coarse sand kept constantly wet with water, and replaced with fresh as fast as it is reduced to powder. When all the surface has become equally rough, it is considered a sign that the glass has been ground to the proper shape, as until that time the projecting parts only show traces of erosion. This is the longest and hardest part of the work, as after that the glass simply needs finishing and polishing. For that purpose emery only can be used, owing to the fact that the material can be obtained of any degrees of fineness, in this respect differing from sand. Otherwise the operation is the same as before, the emery being always kept moistened, and replaced when worn out. The grinding is continued until both the neck of the bottle and the stopper acquire a uniform finish, of a moderate degree of smoothness, and until the stopper fits so accurately that no shake can be felt in it, even though it be not twisted in tightly.

2.—In stoppering a bottle, there are two processes; (a) The mouth of the bottle is opened to the required size by a steel cone revolving in a lathe; (b) the stopper is fixed in a wooden chuck, reduced to proper dimensions, and finally ground into the mouth of the bottle.

Removing.—1.—Place the bottle firmly on a table, and hold it with the left hand. Then apply the right hand to the stopper, and pull it forcibly on one side, using the thumb as a fulcrum at the exterior of the neck of the bottle. If the stopper moves, the motion will be indicated by a ticking kind of noise; and the stopper can then be withdrawn without further trouble. 2.—Tap the stopper on alternate sides with the handle of a hammer, or with a piece of wood (not resting it on a hard substance, but holding the bottle in the hand or between the knees) it can frequently be loosened. 3.—Dip one end of a cloth in boiling water, and then wrap it round the neck of the bottle; the heat causes the neck to expand which allows the stopper more room, whereby it can often be removed with ease. 4.—The flame of a candle or small lamp may be applied to the neck of the bottle with the same effect. But in both cases the operation must be performed quickly, in order that the heat may not get at the stopper and expand it, for if such is the case, it remains as firmly fixed as before. 5.—Pass a piece of strong twine round the neck of the bottle and fix one end of the string to a hook; the neck will be heated by the friction occasioned by drawing the bottle rapidly backwards and forwards, the bottle being held in one hand, and the free end of the string in the other. The heat expands the neck as before described.

Writing on Glass

Ether, 500 gr.; candarac, 30 gr.; mastic, 30 gr. Dissolve, then add benzine in small quantities till the varnish, spread on a piece of glass, gives it the aspect of roughened glass. The varnish is used cold. To have a homogeneous layer, pour over that already formed, some oil of petroleum, let it evaporate a little, then rub in all directions with cambric cloth till all is quite dry. With ink or lead pencil, lines can be produced on this surface as fine as may be desired. Thus a drawing may be prepared in a few minutes and immediately projected.

CHAPTER VII.

HEAT TREATMENT OF METALS—ANNEALING, BRAZING, CASEHARDENING, HARDENING, TEMPERING AND WELDING

The distinction between "Hardening" and "Tempering" should be closely drawn. The word temper refers to the process of drawing temper after steel work has been hardened.

Oil tempering furnaces are designed to heat oil or tallow to about 600° F. and to control the temperature so as to draw any desired temper required in dies, cutters, punches, knives, shear blades, etc., which do not need to show the temper color.

Air tempering furnaces are used to draw, "spring temper" and for all work which must show a temper color.

Sand tempering machines are designed for special work to be drawn to any desired temper color, which must show on the surface, and especially for heavy pieces which cannot be heated quickly enough in hot air and require that they be kept in motion.

ANNEALING

Brass or Copper

In working brass or copper it will become hard, and if hammered to any great extent will split. To prevent cracking or splitting, the piece must be heated to dull red heat and plunged in cold water; this will soften it, so it can be worked easily. Be careful not to heat brass too hot, or it will fall to pieces. These pieces must be annealed frequently during the process of hammering.

Cast Iron

To anneal cast iron, heat it in a slow charcoal fire to a dull red heat; then cover it over about 2 inches with fine charcoal; then cover with ashes. Let it lie until cold. Hard cast iron can be softened enough in this way to be filed and drilled.

Wrought Iron

Chains.—Get your chain to a cherry red or bright red heat (it need not remain in the furnace or fire afterward), then bury in charcoal dust or fine ashes until thoroughly cold. Chains are generally made from "best best" iron, and are more liable to crystallization than more common iron would be, as it is purer.

Steel

1.—More steel is injured, and sometimes spoiled, by over-annealing than in any other way. Steel overheated in annealing will shrink badly when being hardened; besides, it takes the life out of it. It should never be heated above a low cherry red, and it should be a lower heat than it is when being hardened. It should be heated slowly, and given a uniform heat all over and through the piece. This it is difficult to do in long bars and in an ordinary furnace. The best way to heat a piece of steel, either for annealing or hardening, is in red hot, pure lead. By this method it is done uniformly, and one can see the color all the time.

2.—For a small quantity, heat the steel to a cherry red in a charcoal fire, then bury it in sawdust, in an iron box, covering the sawdust with ashes. Let it stay until cold. For a larger quantity, and when it is required to be very soft, pack the steel with cast-iron (lathe or planer) chips in an iron box as follows: Having at least half or three-quarters of an inch in depth of chips in the bottom of the box put in a layer of steel, then more chips to fill the spaces between the steel and also the half or three-quarters of an inch space between the sides of the box and steel, then more steel; and lastly, at least one inch in depth of the chips, well rammed down on top of the steel. Heat the whole to and keep at a red heat for from two to four hours. Do not disturb the box until cold.

3.—Water Annealing.—a.—First heat the steel to a red heat; let it lie until nearly black hot, then throw into soapsuds. Steel treated in this way can be annealed softer than by putting it into the ashes of a forge.

b.—It is now recommended as a good method of annealing steel to let it remain

in the fire until red hot, as it heats more evenly, then take it from the fire and carry it to some dark place, allowing it to cool in the air until the dull red is no longer obvious in the dark, and finally cooling it off in hot water.

BRAZING

1.—If gas can be procured, it makes by far the best brazing heat, is clean, and in using it one has the advantage of being able to place his work to the best advantage and to be able to see exactly what he is doing during the brazing process. Gasoline forges are about half way between gas and coal forges. The greatest difficulty with most gasoline forges is that they do not give enough heat for good-sized jobs. If neither gas nor gasoline are available, then the coal forge must be used; but in doing any kind of brazing, only good clean coal can be used, and coke or charcoal if possible. For cast-iron brazing the coal must be practically free of sulphur. Malleable iron is not so difficult to braze, and almost any means of heating may be used, and an ordinary flux (borax, boric acid, or anything of that nature) will cause the brass to run over it like water.

Malleable iron, steel, or common iron brazing is usually successful, but cast iron is more difficult. The principal difference in brazing cast iron is that a special flux must be used, and a greater heat and a longer time are required. The following flux is recommended: Boric acid, 1 lb.; purverized chlorate of potash, 4 oz.; carbonate of iron, 3 oz. Mix this thoroughly, rolling out all the lumps, and then add 2 lbs. of graulated yellow brass spelter. This flux must be kept perfectly dry. A big fruit jar with the top screwed on tight may be used, and only a little taken out as needed. To use this, arrange the pieces of cast iron to be brazed in such a way that they will not jar out of line during the brazing, and the break so that the brass and flux has a chance to flow down through it. Let the heat come from below, no matter what kind of forge is used. If using gas, throw the blast so that the flame will deflect upward. Heat the piece to a bright cherry red before applying the mixture. Then, using an iron rod, flattened on the end and heated red, apply the flux and brass, rubbing it along the break and working it in lightly, gradually raising the heat till the piece is nearly white. Keep applying the mixture for some time after it has begun to flow nicely, and when you are sure that the flux has flowed all through the break, shut off the fire and let it cool down slowly. Do not hurry the heat, brazing, or cooling. If you have taken care that the break was clean and free from grease in the first place, and have followed directions faithfully, you will be astonished at the strength of the brazed joint. It will not break in the same place again, but will break either some distance away or across the first fracture. You cannot tear apart a good cast-iron braze. In trying this flux for the first time, do not use too small a piece, but take a cast-iron bar, say 1 x 1 x 12 in., break in two in the middle, and experiment on that till you get used to the right heat and the action of the flux. After thoroughly testing out this you may begin on smaller articles, but remember that on very small pieces fire-brick or clay must be built up around them in order to hold in the heat, as a small piece nasn't body enough itself to properly fuse the flux. This flux can be also used for welding and makes an unusually good compound. Any first-class druggist can supply the ingredients, and if no spelter can be obtained, chop up some soft brass rod, sheet or scrap, and mix in; but remember, do not apply flux till your iron is at least cherry red; the hotter the better, just so the iron doesn't melt. For ordinary brazing, such as bicycle frames and the like the following flux is recommended: Boiling water, 1 pt.; borax, 1 pt. Let this dissolve thoroughly; then add 2 pt. of boric acid. No care need be taken of this flux other than to keep the dirt out of it. When using it dry, add a little water and paint the article wherever brass is wanted to flow. This should be done before heating, after heating more flux and brass is applied. Brass will follow this flux "uphill" for an inch or so. This flux, however, has no effect whatever on cast iron.

2.—Probably for some kinds of work borax will never be improved upon for a flux, but for some other varieties of brazing borax does not completely fill the bill—as, for example, when brazing work which must be filed and cannot be ground. Then the borax will leave a very hard skin, which destroys many a file before it is fully removed. For this kind of work some mechanics like to use boracic acid, putting it on with a brush or a swab. The hard skin is thinner, and comes off easier when the acid solution is used, but a writer in the *Tradesman* is of opinion that the difference lies mostly in the fact that not so much of the flux is used when the solution is employed. The usual way is to pound up a lot of lump borax in a lead-melter's ladle or the hollow of a blacksmith's sow. Some

of this (usually very coarse) powder is placed on the work with a bit of flat iron. Too much borax for the purpose is necessarily used in this manner, and the excess goes to make up the hard skin which "does for" the files. When the acid is used the same effect is secured as when the solid borax is applied, but not one-tenth the amount is used, and that is applied just where it is needed. If, for any reason, the manager insists upon a solid borax being used, make that official secure a coffee mill (one of the old-fashioned cheap ones will answer perfectly) and have all the borax ground very fine. Then a little of the dust powder can be rubbed or dusted on where the joint is to be made, and the braze made without having a lot of oxide and slag piled up around the work.

Aluminum

Aluminum bronze will braze as well as any other metal by using ¼ brass solder (copper 50%, zinc 50%), and ¾ borax.

Steel

The following solder will braze steel, and may be found very useful in case of a valve stem or other light portion breaking when it is important that the engine should continue to work for some time longer: Silver, 19 parts; copper, 1 part; brass, 2 parts. If practicable, charcoal dust should be strewed over the melted metal of the crucible.

CASEHARDENING

1.—A reliable method is to place the pieces to be hardened in an iron box made airtight by having all its seams covered well with fireclay, filling the box in with bone dust closely packed around the articles, or (what is better) with leather and hoofs cut into pieces about an inch in size, adding thin layers of salt in the proportion of about 4 lb. salt to 20 lb. of leather and 15 lb. of hoofs. In packing the articles in the box, be careful to so place them that when the hoofs, leather, etc., are burned away, and the pieces of iron in the box receive the weight of those above them, they will not be likely to bend from the pressure. When the articles are packed and the box ready to be closed with the lid, pour into it 1 gal. of urine to the above quantities of leather, etc.; then fasten down the lid and seal the seams outside well with clay. The box is then placed in a furnace and allowed to remain there for about twelve hours, when the articles are taken out and quickly immersed in water, care being taken to put them in the water endways to avoid warping them. Articles to be casehardened in the above manner should have pieces of sheet iron fitted in them in all parts where they are required to fit wlll and are difficult to bend when cold. Suppose, for instance, it is a quadrant for a link motion: fit into the slot where the die works a piece of sheet iron (say ¼ in. thick) at each end of the slot, and two other pieces at equidistant places in the slot, leaving on the pieces a protection to prevent them from falling through the slot. In packing the quadrant in the box, place it so that the sheet iron pieces will have their projections uppermost; then in taking the quadrant out of the box, handle it carefully, and the pieces of iron will remain where they were placed and prevent the quadrant from warping in cooling or while in the box, from the pressure of the pieces of work placed above it. It is obvious from what has been already said that the heavier pieces of work should be placed in the bottom of the box.

2.—Small Articles.—Take a length of gas pipe of from 6 to 12 in. and of suitable diameter, screw on thimble caps, and pack the screws in them with bone dust, or with equal parts of charcoal dust and unslaked lime; heat to a red for 2 hours, then chill in cold water. A charcoal or a coke fire is best; anthracite will do, but bitumous coal is objectionable.

3.—Sal soda, 27 parts; lampblack, 24 parts; sodium chloride, 6 parts; black oxide manganese, 1½ parts.

4.—Take some good charcoal (from oak the best); also some marble (carbonate of lime). Mix together, the marble having been broken small. Then lay the tool or other piece to be casehardened in this compound, in a covered box, and subject it to good and continuous heat. Result: a deep penetration of the carbon into the iron, and therefore a coating of steel. In other words, the outer cuticle has been converted into steel by the process of cementation.

5.—A mixture said to be very efficacious for casehardening iron consists of 16 parts of lampblack, 18 parts sal soda, 4 parts muriate of soda, 1 part black oxide of manganese.

Iron

Prussiate of Potash Process.—1.—Crush the potash to a powder, being careful that there are no lumps left in it, then heat the iron as hot as possible without causing it to scale; and with a piece of rod iron, spoon-shaped at the end, apply the prussiate of potash to the surface of the iron, rub it with the spoon

end of the rod until it fuses and runs all ver the article, which must then be placed in the fire again and slightly reheated, and then plunged into water, observing the rules given for immersing steel so as not to warp the article.

2.—Powder the prussiate of potash and spread upon the surface of the piece of iron to be hardened, after the iron is heated to a bright red. It almost instantly fluxes or flows over the surface, and when the iron is cooled to a dull red it is plunged into cold water. Some prefer a mixture of prussiate of potash, 3 parts; sal ammoniac, 1 part; or prussiate, 1 part; sal ammoniac, 2 parts, and finely powdered bone dust (unburned), 2 parts. The application is the same in each case. Proper casehardening, when a deep coating of steel is desired, is done by packing the article to be hardened in an iron box with horn, hoof, bone dust, shreds of leather or raw hide, or either of these, and heated to a red heat, for from 1 to 3 hours, then plunged in water.

HARDENING

Copper

1.—Mix thoroughly when in a molten condition with from 3 to 5% of manganese oxide.

2.—Copper treated as follows becomes harder and tougher than commercial hard copper: Take 2 lb. of alum and 8 oz. of arsenic, and mix well. 40 lb. of copper is to be used with this quantity of alum and arsenic. When the copper is thoroughly melted the alum and arsenic are poured in the crucible, and mixed well with the melted copper. The copper is then poured, and allowed to cool gradually.

Iron

Cast.—1.—Salt, ½ pt.; saltpeter, ¼ lb.; prussiate of potash, ⅛ lb.; cyanide of potash, ¼ lb.; soft water, 5 gal. Heat the iron to a cherry red, dip in the mixture. If not hard enough repeat the process.

2.—1 lb. of strong sulphuric acid is mixed with 1½ gal. water and 1 oz. of nitric acid. Heat the iron in a clean fire to a cherry red, and plunge into the mixture.

3.—For cooling and hardening cast iron: To 60 l. of water add 2.5 l. of vinegar, 3 kgm. of common salt and 0.25 kgm. of hydrochloric acid.

Steel

1.—A new process of hardening steel is to coat the metal with a mixture of whiting and varnish, heat to a cherry red, and to then dip for a few seconds in acidulated water. The steel is then dipped in rape oil for a slightly longer time, and is finally laid in a cooling bath of rock oil or a mixture of water and whiting. By dipping the steel first in the water, the heat is drawn away from the outer layer, which thus becomes hard. Dipping it in the rape oil retards the cooling of the interior of the metal, and obviates the risk of cracks appearing.

2.—To 1 lb. of prussiate potash add 3 lb. common salt, 2 oz. borax, and 2 oz. cyanide potash. Place the same in a crucible and place the same over a fire; when hot put the steel in the mixture and there let it remain until hot, after which immediately plunge it in water until cool. This prevents the steel from cracking or warping, and will give perfect satisfaction.

SOFTENING STEEL

1.—Place a quantity of newly burnt lime in a damp place, where it will fall in the form of flour; put it in an iron box. Heat the articles to dull red; clean off all scale, and put in lime, and completely cover with lime; cover box over with iron lid and leave until cold. The more lime and larger the box the better. Keep airtight if possible.

2.—One tablespoonful each of hydrochloric acid and saltpeter to 1 gal. of water. Heat the steel and cool in it; then heat to soften by letting cool. Cast steel thus treated will weld with sand.

TEMPERING

Steel

1.—In judging the proper temperature and corresponding hardness, the following table serves admirably. It is often difficult to heat a piece of steel uniformly, consequently molten metallic mixtures are employed, chiefly made up of tin and lead; the bright hardened steel is kept in these molten mixtures until it has assumed the temperature of the bath. The tabulated form on the following page exhibits the composition of the metallic baths which have been found to be the best for tempering cutlery.

2.—(a) Use animal charcoal produced by charring horn, 24 parts; horn filings, 4 parts; glue, 6 parts; potassium nitrate, 9.5 parts; common salt, 55 parts. (b) Potassium bicyanide, 1 part; purified saltpeter, 1 part; burnt and powdered cattle hoofs, 1 part; gum arabic, 1-30 part; aloes, 1-30 part; common salt, 0.5 part Mix a and b well together after being well pulverized, strew this upon steel when red hot and upon wrought iron when white

	Composition of metallic mixtures. Lead.	Tin.	Melting. point.	Colors.
Lancets	7	4	220°	Hardly pale yellow
Razors	8	4	228°	Pale yellow to straw yel.
Penknives	8½	4	232°	Straw yellow
Pairs of scissors	14	4	254°	Brown
Clasp knives, joiners' and carpenters' tools	19	4	265°	Purplish colored
Swords, cutlasses, watch springs	48	4	288°	Bright blue
Stilettos, boring tools and fine saws	50	2	292°	Deep blue
Ordinary saws	Boil'g linseed oil		316°	Blackish blue

hot, and allow it to burn in, after which cool as usual.

3.—Cast Steel.—Dissolve a small quantity of sal ammoniac in water, make the metal red, drop it into the mixture for a second or two, and take it out, leaving enough heat in the metal to draw it back a bit. If left till cold, the steel will be a great deal too hard.

Cold Chisels.—Heat the chisel at a low heat, so as not to raise a scale. Dip in a brine of clear salt and water. About 1 qt. of salt to 10 qt. of water is the right proportion. Leave heat enough in the tool to run the temper down to a required hardness, which is shown by the pigeon blue color. Take care to make the chisel stout enough that it won't spring in the using.

Drill.—1.—A drill heated to a low red, and plunged in a strong solution of chloride of zinc, will drill glass.

2.—Heat the drill and rub in cyanide of potassium. The drill should be hot enough to melt the potassium. Heat again to a dark cherry red, and cool it in a very strong brine made with warm, soft water. Do not draw the temper. The drill will look white, but be hard and tough.

Gun Springs.—To temper gun springs, heat them evenly to a low red heat in a charcoal fire, and quench them in water with the cold chill off, keeping them immersed until reduced to the temperature of the water. Place an iron pan containing lard oil and tallow, in about equal quantities, over a fire, and place the springs therein, and heat the pan until its contents take fire; then hold the springs in the flames, turning them over and over and dipping them occasionally in the oil to keep them blazing; when the oil adhering to them blazes freely when they are removed from the flames, place them aside to cool off.

Knife Blades.—Be careful about heating, otherwise the blade will be warped out of shape. When the blade is heated evenly, plunge perpendicularly in a bath of raw linseed oil. The temper should be drawn on a hot iron. The blades may be heated and hardened between two straight pieces of iron.

Liquid for Tempering.—1.—Saltpeter, 1 oz.; alum, pulverized, 2 teaspoonfuls; salt, 1 teacup; soft water, 2 gal.; never heat over a cherry red nor draw any temper.

2.—Water, 7½ gal.; saltpeter, 5 oz.; sal ammonaic, 5 oz.; alum, 5 oz. Draw to temper.

3.—Water, 2 gal.; saltpeter, 2 oz.; alum, 2 oz.; sal ammoniac (pulverized), 1 oz.; salt, 1½ lb. Heat to a cherry red, plunge in, draw no temper.

4.—Water, 2 gal.; saltpeter, ½ oz.; pulverized borax, ½ oz.; white vitriol, 1 oz.; salt, 1½ pt.

5.—Put ½ oz. of corrosive sublimate in 3 qt. of soft water and add 1 handful of common salt. Dissolve, and it is ready for use. This gives toughness and hardness of steel. It is a dangerous poison.

Springs, To Temper.—1.—Tempering of coiled springs requires must judgment, based upon experience with the particular kind of spring that you wish to temper. A coiled spring does not give the faintest idea of its form, size, length, thickness, kind of steel, or whether it is a clock spring or car spring, all of which must be considered in the method of treatment. As a general rule, springs that are slender and liable to lose shape in a common fire should be heated in an oven or muffle and hardened in water or oil. The temper should be drawn in boiling linseed oil. Springs that have stiffness, like car springs, may be heated in a covered forge fire to good advantage and hardened in lard oil. The temper can be drawn by burning off.

2.—Heat to an even red heat, rather low, to prevent cracking; quench in lukewarm water. Place in ladle with enough tallow to cover it; heat until tallow burns with a large flame extending beyond ladle,

then set the ladle aside and allow it to cool.

3.—Revolver Springs.—Heat the spring to a cherry red and plunge in linseed oil. To draw the temper to the desired degree, hold the spring over the fire, and allow the oil to burn away, take away from the fire, put on more oil, and let it burn away. Burn the oil off three times and plunge in the oil again. The spring is then ready for use. Do not overheat the steel. Test the temper frequently with a file.

Taps.—Bear in mind that a tap is simply a series of cutters on a bar; hence the cutting parts must be uniformly hard enough to cut, and the base soft as possible to insure durability. This can be best accomplished by dipping at as low a heat as possible and making the outside hard, while the inside will be comparatively soft when rubbed off ready for tempering. Heat a heavy ring (a broken pulley hub is as good as anything), which have on side of your fire for use while hardening taps, and also a heavy pair of tongs, made hot in the same way. Take the lever end of the tap with the hot tongs, and insert the tap in the center of the hot ring, but do not let it touch the sides. It is better to keep turning it round. If the temper draws too fast, where held by the tongs, cool it off, move backward and forward until the right color is attained. This, too, depends on quality of steel and the size and make of the tap, and lastly the purpose for which it is intended.

WELDING

Directions

The great secret of welding is to have a clean fire, then heat the iron and "strike while the iron is hot." Make the fire of blacksmiths' coal which has been caked (coke). If the work is small have only a little fire. As the weld requires considerable pounding, plenty of stock should be left by using generous laps. Be sure the laps fit well before welding. When the iron gets from a red to a white heat sand the iron without removing from the fire and watch the iron carefully. When it sparks freely and has a glazed appearance, remove from the fire, lay quickly, after a shake to remove the oxide, and pound the lap well until the iron becomes too cold to work.

Composition for.—1.—To 20 parts of iron filings add 10 parts of borax and 1½ part sal ammoniac and 1 part of balsam of copaiba or other resinous oil. Mix well, heated and purverized. The surfaces to be united are powdered with this mixture; after which place the article in the fire and let it come to a cherry-red heat; when the composition melts, take the portions to be welded from the fire and join together. This composition is used in Germany with great success.

2.—Another composition for welding consists of 30 parts of borax, 4 parts of sal ammoniac and 4 parts of cyanide of potash. Dissolve in water and then evaporate the water at a low temperature.

Copper.—Prepare a mixture of 358 parts soda phosphate, 124 parts boracic acid; apply the powder when the metal is at a dull red heat; it is then brought to a cherry red and at once hammered. As the metal is apt to soften when exposed to a high degree of heat, a wooden hammer is recommended. Remove all carbonaceous matter from the surfaces to be joined, as the success of the operation depends on the formation of a fusible phosphate of copper. The prosphate of copper dissolves a thin film of oxide on the surfaces of the metal, keeping them clean and in condition to weld.

Fluxes.—1.—A welding material composed of 25 parts of borax, a paper or metallic support and 60 parts metallic filings of the same nature as the metals to be welded, and made by first melting the borax; second, immersing the support in the fused borax; third, smoothing the same by passing it through pressure rollers; fourth, sprinkling its two faces with the metal filings; fifth, heating the sheet in an oven; sixth, passing through pressure rollers.

2.—A welding material composed of borax and metallic filings of the same nature as the metals to be welded, mixed with the fused borax, and in the proportions substantially as set forth, and then rolled out into sheets of about 1-16 in. thick.

3.—The welding sheets coated with a layer of gum lac or other appropriate varnish.

4.—The following compound has been frequently offered as a trade secret: Take copperas, 2 oz.; saltpeter, 1 oz.; common salt, 6 oz.; black oxide of manganese, 1 oz.; prussiate of potash, 1 oz. Pulverize these ingredients and mix with them 3 lbs. nice welding sand.

Lead.—An ingenious method of welding lead has been devised by M. Blondel. The surfaces to be joined are carefully cleaned and between them is placed a thin layer of lead amalgam. On passing an ordinary soldering iron along the line of junction, the mercury of the amalgam is vaporized, and the lead, set free in an exceedingly finely divided state, fuses and unites the two surfaces together.

Powder.—Belgian Welding Powder.—1.—Iron filings, 800 parts; borax, 400 parts; balsam of copaiba or other resinous oil, 40 parts; sal ammoniac, 60 parts. Mix, heat and pulverize finely. Powder the surfaces to be welded, bring to a cherry-red heat, at which the powder melts; take from the fire and join.

2.—Calcine and pulverize together 50 parts iron or steel filings, 5 parts sal ammoniac, 3 parts borax, 2½ parts balsam copaiba. Heat one of the pieces to be welded red, carefully clean off scale, spread the powder upon it; apply the other piece at a white heat and weld with a hammer. Used for welding iron and steel, or both, together.

Iron and Steel Together.—1.—To weld cast steel with cast steel or with iron, a welding powder has to be made use of, if a secure seam is desired, since cast steel cannot stand sparkling heat. An excellent welding powder is produced as follows: In an unglazed iron vessel or crucible fuse borax in an annealing furnace until the liquid appears entirely dark green. Test the molten mass by immersing a wire or piece of iron, to which a sample will cling. First the molten mass is pale yellow, but it gradually turns darker. As soon as the sample taken with the iron rod, which immediately cools into a hard mass, acquires a dark green or black color, the moment has arrived to remove the vessel from the fire in order to pour the contents into another cold, but dry, receptable. After complete cooling, the glass-like dark mass is crushed in a mortar into a coarse powder. The powder is pale greenish yellow, and is now mixed with an equal volume of steel filings. In storing the welding powder it must occupy a dry place to prevent the filings from rusting.

2.—Heat the steel to cherry red (after it is shaped to correspond to the surface of the cast iron to which it is to be joined). Apply borax to the surfaces to be welded. Heat the parts to a welding heat. Apply strong pressure, without immersing, which will securely weld the steel and iron.

3.—Ten parts borax, 1 part sal ammoniac; pulverize together thoroughly, with which sprinkle the parts to be welded.

4.—To make composition used in welding cast steel, take of borax 10 parts; sal ammoniac, 1 part; grind or pound roughly together; then fuse in a metal pot over a clear fire, continuing the heat until all spume has disappeared from the surface. When the liquid appears clear, the composition is ready to be poured out to cool and concrete. To prepare it for use it is ground to a fine powder. The steel to be welded is raised to a bright yellow heat, and then dipped into this welding powder; it is then placed in the fire again, and when it attains the same heat as before it is ready to be placed under the hammer.

5.—Welding Cast Steel Without Borax.—Copperas, 4 parts; saltpeter, 2 parts; prussiate of potash, 2 parts; black oxide of magnesia, 2 parts; common salt, 12 parts; all pulverized. Mix with good welding sand, 48 parts, and use precisely the same as you would sand.

6.—Powder to weld wrought iron at pale-red heat with wrought iron: Borax, 1 part (by weight); sal ammoniac, ½ part; water, ½ part. These ingredients are boiled with constant stirring until the mass is stiff; then it is allowed to harden over the fire. Upon cooling the mass is rubbed up into a powder and mixed with one-third wrought-iron filings free from rust. When the iron has reached red heat this powder is sprinkled on the parts to be welded, and after it has liquefied a few blows are sufficient to unite the pieces.

7.—Welding powder to weld steel on wrought iron at pale-red heat: Borax, 3 parts; potassium cyanide, 2 parts; Berlin blue, 1-100 part. These substances are powdered well, moistened with water; next they are boiled with constant stirring until stiff; then dry over a fire. Upon cooling the mass is finely pulverized and mixed with 1 part of wrought-iron filings free from rust. This powder is sprinkled repeatedly upon the hot pieces, and after it has burned in the welding is taken in hand.

CHAPTER VIII.

LUBRICANTS

General Information on Lubricants

The general experience gained of various oils used for lubricating tends to the following results:

1.—A mineral oil flashing below 300° F., 149° C., is unsafe, on account of causing fire.

2.—A mineral oil evaporating more than 5% in 10 hours at 140° F., 60° C., is inadmissible, as the evaporation creates a vicious residue, or leaves the bearing dry.

3.—The most fluid oil that will remain in its place, fulfilling other conditions, is the best for all light bearings at high speeds.

4.—The best oil is that which has the greatest adhesion to metallic surfaces and the least cohesion in its own particles. In this respect, fine mineral oils are first, sperm oil second, neatsfoot oil third, lard oil fourth.

5.—Consequently, the finest mineral oils are best for light bearings and high velocities.

6.—The best animal oil to give body to fine mineral oils is sperm oil.

7.—Lard and neatsfoot oils may replace sperm oil when greater tenacity is required.

8.—The best mineral oil for cylinders is one having sp. gr. 0.893 at 60° F., 15½° C.; evaporating point, 550° F., 288° C., and flashing point, 680° F., 360° C.

9.—The best mineral oil for heavy machinery has sp. gr. 0.880 at 60° F., 15½° C.; evaporating point, 443° F., 229° C., and flashing point, 518° F., 269° C.

10.—The best mineral oil for light bearings and high velocities has sp. gr. 0.871 at 60° F., 15½° C.; evaporating point, 424° F., 218° C., and flashing point 505° F., 262° C.

11.—Mineral oils alone are not suited for the heaviest machinery, on account of want of body and higher degree of inflammability.

12.—Well purified animal oils are applicable to the very heavy machinery.

13.—Olive oil is foremost among vegetable oils, as it can be purified without the aid of mineral acids.

14.—The other vegetable oils admissible, but far inferior, stated in their order of merit, are gingelly, ground nut, colza and cotton-seed oils.

15.—No oil is admissible which has been purified by means of mineral acids.

16.—In the case of all lubricants it is necessary to remember that a given recipe is suitable for a certain climate only, and must be correspondingly modified to suit warmer or colder districts.

Cleaning Lubricating Oil.—Agitate it with a small percentage of oil of vitriol, and then thoroughly wash it with water by agitation; siphon off the oil and let stand over quicklime. To filter oil from mechanically contained impurities, fit a small cork, cut star-shaped, in the angle of a funnel, so that it will not impede the passage of liquids, and cover this loosely with cotton wool (raw cotton). If properly arranged, the oil will pass through, leaving the impurities in the cotton.

Purifying Lubricating Oil.—The following is a good method of purifying lubricating oil: A tub holding 63 qt. has a tap inserted close to the bottom and another about 4 in. higher. In this receptacle are placed 7 qt. of boiling water, 3½ oz. of carbonate of soda, 3¼ oz. of chloride of calcium, and 9 oz. of common salt. When all these are in solution, 45 qt. of the oil to be purified are let in, and well stirred for 5 or 10 minutes; the whole is then left for a week in a warm place, at the expiration of which time the clear, pure oil can be drawn off through the upper tap without disturbing the bottom one.

Testing Lubricating Oil.—To test lubricating oil for acid, dissolve a crystallized piece of carbonate of soda, about as large as a walnut, in an equal bulk of water, and place the solution in a flask with some of the oil. If, on settling, after thorough agitation, a large quantity of precipitate forms, the oil should be rejected as impure.

Solid Lubricants

Caoutchouc Lubricants. — 1. — Caoutchouc grease.—Train oil, 200 parts; caoutchouc, 20 parts. The train oil is heated in a pan until it begins to decompose, this condition being revealed by

an ebullition resembling boiling, and by the evolution of a disagreeable smell, the caoutchouc, cut into small pieces, being introduced by degrees, and the entire mass vigorously stirred after each addition. For ordinary purposes, this grease is inapplicable, owing to the high price of caoutchouc, the more so because lubricants of at least equal efficiency can be prepared at a far cheaper cost.

2.—Caoutchouc and Fat Grease.—Caoutchouc, 5 parts; palm oil, 100 parts; rape oil, 100 parts; tallow, 50 parts. The caoutchouc is dissolved in the rape oil by the aid of a high temperature, and the filtered solution is incorporated with the solid fats. It has been found by experiment that actual filtration of the mass is impracticable, it being difficult to strain even through a linen cloth.

Lead Soap Lubricants.—The lead salts possess the property of saponifying fats or fatty oils to form fairly solid compounds, known as lead soaps, which are hard in the cold, and smeary at the ordinary temperature, but attain the necessary degree of fluidity when warmed by friction. This latter property is highly important in the case of the axles of vehicles, since it reduces the loss of grease, by dropping to a minimum. For the preparation of these lubricants it is, first of all, necessary to make a solution of basic lead acetate, or sugar of lead, which is then incorporated with a suitable proportion of fat. The solution is prepared from sugar of lead, 10 parts; litharge, 10 parts; water, 110 parts. Boil 1½ to 2 hours, stirring repeatedly, at the end of which time the mass is left to rest, and the clear liquid drawn off. The latter is made up to 100 parts, by weight, by the addition of water, and after being warmed to about 120 to 140° F., is mixed with common fat (rape oil and pork fat, or neatsfoot oil), in the following proportions: Sugar of lead, 100 parts; rape oil, 80 parts; pork fat, 80 parts. The resulting preparation should be of a uniform gray color, and when melted should set again at 85 to 105° F.

Naphthalene Grease.—Naphthalene, 100 parts; rape oil, 50 to 100 parts. The naphthalene—a crystalline hydrocarbon recovered from coal tar—is melted, and stirred up with a larger or smaller quantity of rape oil, the product varying in consistency between firm, buttery and fluid, and forming a useful lubricant. The expensive purified naphthalene is not meant here, purity not being an essential feature for the purpose in view; so that the crude article, which is very impure, is sufficient. These remarks apply equally to paraffine.

Soap Greases.—The soap greases, properly so called, are prepared with ordinary soft soap (a compound of potash with fatty acids), or from fats and potash, these forming the emulsions already referred to. Tallow, 420 parts; olive oil, 360 parts; potash, 60 parts; water, 650 parts. The potash is dissolved in water, the solution heated to boiling, and the whole of the fat is added at once, the fire being made up so as to keep the whole in a liquid state. Boiling is continued, with constant stirring, until complete saponification is indicated by the thickening of the mass and the way in which a sample will draw into threads on cooling. The resulting product is, in a chemical sense, really a dilute solution of potash mixed with an excess of fat, and may, therefore be regarded as an emulsion lubricant in the true sense of the term.

Tallow Lubricants.—Tallow grease is always a serviceable article, but it is somewhat dearer than other lubricants. Tallow changes in consistency very considerably according to the temperature. In the height of summer it is on a par with soft butter, but perfectly hard and friable in very cold weather.

1.—Booth's Patent Grease.—a.—Refined tallow, 6 parts; palm oil, 12 parts; water, 8 parts; soda, 1 part.

b.—Refined tallow, 8 parts; palm oil, 20 parts; water, 10 parts; soda, 1½ parts.

For both recipes the tallow is melted first, and heated to about 265° F., the palm oil being stirred in. The soda is dissolved in water, in a separate vessel, either at ordinary temperature or by the aid of warmth, and the solution is run, in the form of a thin stream, into the mixture of tallow and palm oil, which is kept constantly stirred the while. After the whole of the soda has been added the fire is drawn, and the mass is stirred until it begins to set and to offer considerable resistance to the stirrers.

2.—Tallow and Neatsfoot-oil Grease.—Tallow, 100 parts; neatsfoot oil, 100 parts. This grease was used for a long time on the Württemberg railways; it is very thick, and, therefore, specially suitable for summer use; but is rather dear.

3.—Tallow, Rape-Oil and Soda Greases.—a.—Winter Grease.—Tallow, 180 parts; refined rape oil, 120 parts; soda, 20 parts; water, 360 parts.

b.—Spring and Autumn Grease.—Tallow, 230 parts; refined rape oil, 85 parts; soda, 20 parts; water, 350 parts.

c.—Summer Grease.—Tallow, 260 parts; refined rape oil, 55 parts; soda, 20 parts; water, 340 parts.

Liquid Lubricants

The liquid lubricants possess many important advantages over the greases, and, in consequence, are often preferred by railway companies and machinery makers. Their chief superiority is that they do not require such complicated appliances (grease boxes) in use, they begin to act as soon as they are applied, without needing the heat generated by friction to make them sufficiently fluid; and, besides, the oiling vessels can be of a simple type, even on the axles of vehicles. Finally, they exhibit the valuable feature of having their consistency less affected by the temperature of the air than is the case with greases. The best materials for the preparation of the liquid lubricants are: 1, rape and colza oils; 2, olive oils; 3, rosin oil, either alone or in association with lime or certain products of dry distillation (paraffine); 4, train oil; 5, neatsfoot oil and bone oil; 6, the so-called mineral oils (solar oil, coal oil); 7, petroleum and ozokerite; 8, soap solutions.

Fat and Rosin Oil.—Rosin oil is miscible with solid and liquid fats in all proportions, and the products exhibit properties corresponding to those of the components of the mixture.

1.—Rosin Oil and Train Oil Lubricant.—Rosin oil, 100 parts; refined train oil, 50 parts. Since this mixture deposits a sediment after standing for some time, it is important that it should not be used as soon as made, but should be stored in vats or casks for a while.

2.—Solar Oil Lubricant.—Solar oil, 30 parts; refined rape oil, 20 parts. This lubricating oil is particularly suitable for brass and bronze machine parts, as it does not corrode these metals to more than an appreciable extent.

3.—Thick Oil Lubricants.—a.—For winter use: Tallow, 35 parts; rosin oil, 10 parts; rape oil or olive oil, 65 parts.

b.—for summer use: Tallow, 60 parts; rosin oil, 8 parts; rape oil or olive oil, 40 parts.

Paraffine Oil Grease.—1.—Summer grease: Paraffine oil, 10 parts; refined rape oil, 90 parts.

2.—Winter grease: Paraffine oil, 6 parts; refined rape oil, 94 parts.

It is self-evident that these recipes can also be modified to furnish greases suitable for medium temperatures—*i.e.*, spring and autumn use—all that is necessary being to increase or diminish the proportion of rape oil accordingly. These paraffine-oil greases, which have hitherto been insufficiently appreciated, form excellent lubricants both for axles and machinery, and can be produced cheaply wherever paraffine oil is easily obtainable. In addition to perfect lubrication they have the advantage of not corroding the machine parts.

3.—Paraffine and Vaseline Grease.—Pure white paraffine and vaseline can be mixed in any proportion by melting them together, and furnish greases ranging in consistency from that of soft butter to thick salve, by varying the quantities. Being perfectly free from acid, they are admirably suited for fine machinery and axles, whether running at high or low speed.

Mineral Lubricating Oils

1.—Thick Mineral Lubricating Oils (Greases).—These oils are prepared by boiling together milk of lime, some vegetable oil and a mineral oil until a homogeneous salve-like mass is obtained. A lime soap is formed, which dissolves in the oils; and the larger the quantity of this soap the higher the melting point of the grease. On account of this high melting point, and the viscosity of the mass when melted, these greases are specially suitable for high-pressure steam engines.

a.—Mineral oil, 100 parts; linseed oil, 30 parts; ozokerite oil, 20 parts; lime, 9 parts.

b.—Mineral oil, 100 parts; linseed oil, 30 parts; ozokerite oil, 20 parts; lime, 5 parts; magnesia, 4 parts.

c.—Mineral oil, 100 parts; linseed oil, 25 parts; ozokerite oil, 35 parts; lime, 10 parts.

d.—Mineral oil, 100 parts; rape oil, 40 parts; cocoanut oil, 10 parts; lime, 10 parts.

e.—Mineral oil, 100 parts; rosin oil, 100 parts; rape oil, 50 parts; linseed oil, 75 parts; lime, 25 parts.

f.—Mineral oil, 100 parts; rape oil, 30 parts; ozokerite oil, 20 parts; lime, 15 parts.

2.—Lanoline Axle Grease.—a.—Rape oil, 10 parts; quicklime, 5 parts; water, 20 parts; crude vaseline, 500 parts; crude lanoline, 40 parts.

b.—Linseed oil, 10 parts; quicklime, 5 parts; water, 20 parts; crude vaseline, 600 parts; crude lanoline, 40 parts.

The last two formulas mentioned above are mixed with clay, soapstone or infusorial earth, in the proportion of 10 to 25% of the whole mass.

3.—Lanoline Lubricant.—In scouring sheep wool, a product known as wool fat, wool yolk, or suint, is obtained, and this

in turn furnishes lanoline, or wool oil. Lanoline, when quite pure, is a soft mass of fatty character, but is not a fat, and therefore never turns rancid, so that it forms an excellent lubricant. It is particularly adapted for axle grease, only the crude lanoline being, of course, used for this purpose. The method of preparation adopted consists in heating some vegetable oil with milk of lime and crude vaseline until a homogeneous mass is obtained, melted lanoline being then added in a thin stream, and stirred with the rest until the product has attained the consistency of soft salve. The mass may be stiffened to any desired extent by the addition of ground soapstone, clay or infusorial earth.

4.—Soap and Vaseline Greases.—Crude vaseline, mixed with ordinary or rosin soap, furnishes a very good railway grease, green to brown in color. Crude vaseline, 6 to 8 parts, melted along with 1 part of tallow and 1 part of colophony, 1½ parts of soda lye (20° Bé.) being poured in as a thin stream, and the whole stirred continuously until the mass begins to get viscous, whereupon it is poured into cans, drums, etc., for sending out.

LUBRICANTS FOR SPECIAL PURPOSES

Axle Grease

In making axle grease for cold countries, the proportion of train oil must be increased to give the grease the necessary fluidity. The larger the quantity of train oil the softer, more buttery, and more easily melted the mixture will be. The following is a recipe for a thick oil grease:

1.—For use in winter: Tallow, 35 parts; oil of rosin, 10 parts; olive or rape oil, 65 parts.

2.—For use in summer: Tallow, 60 parts; oil of rosin, 8 parts; olive or rape oil, 40 parts.

The blue color is due to the dark violet tint of the oil referred to, while the yellow tint is produced by the addition of a solution of turmeric root in caustic soda.

Asphaltum Axle Grease.—Asphaltum, 32 parts; black pitch, 8 parts; petroleum, 8 parts; litharge, 8 parts; water, 80 parts. The asphaltum and pitch are first melted together in a pan, the petroleum being then added until the mass has become uniformly fluid. The litharge is next added, and finally the water is run in, in small quantities, the whole being stirred until perfectly uniform. The asphaltum and pitch give this grease a lustrous black color and a peculiar bituminous smell. The fluidity of the mass can be increased or diminished by correspondingly varying the proportion of petroleum.

Car Axles.—Dark ozokerite, 15 parts; heavy petroleum, 3 to 6 parts. Melt together at a gentle heat. Suitable also for heavy wagons.

Carriage Axle Greases.—1.—Tallow, 500 parts; linseed oil, 500 parts; pine rosin, 500 parts; caustic soda lye, 315 parts.

2.—Tallow, 500 parts; linseed oil, 450 parts; pine rosin, 500 parts; caustic soda lye, 500 parts.

Both preparations, when suitably stirred during preparation, form solid masses, of the constituency of salve, and yellow in color. They are easily distributed on the axles, and lubricate well. The rosin is melted first, the tallow and linseed oil being then added; and when these have formed a uniform mixture, the caustic soda lye is added by degrees. The lye is used moderately strong, and the firmness of the grease can be heightened by increasing the concentration of the alkaline solution.

Frazer's Axle Grease.—Composed of partially saponified rosin oil, that is a rosin soap and rosin oil. In its preparation ½ gal. of No. 1 and 2½ gal. of No. 4 rosin oil are saponified with a solution of ½ lb. of sal soda dissolved in 3 pt. of water, and 10 lb. of sifted lime. After standing for 6 hours or more, this is drawn off from the sediment and thoroughly mixed with 1 gal. of No. 1, 3½ gal. of No. 2, and 4 2-3 gal. of No. 3 rosin oil. This rosin oil is obtained by the destructive distillation of common rosin, the products ranging from an extremely light to a heavy fluorescent oil, or colophonic tar.

Graphite Axle Grease.—Tallow, 36 parts; pork fat, 9 parts; palm oil, 9 parts; graphite, 2 parts.

Graphite Grease for Quick-Running Axles.—Tallow, 100 parts; graphite, 10 parts. This is specially suitable for greasing the shafts of circular saws, ventilating fans, etc., and, indeed, for any axles running at high speed under small load.

Palm Oil Axle Greases for Very Heavy Wagons.—1.—For winter use: Tallow, 420 parts; palm oil, 840 parts; soda, 140 parts; water, 4,200 parts.

2.—For summer use: Tallow, 420 parts; palm oil, 490 parts; soda, 35 parts; water, 2,300 parts. The above are calculated for severe winter weather and high summer temperatures. For milder

winter climates the proportion of soda may be somewhat reduced and the palm oil increased.

Belting Grease

1.—To 100 parts of castor oil add 10 parts of tallow. Belts lubricated with this mixture are made flexible, and the friction on the pulleys is increased.

2.—Linseed oil, 9 parts; litharge, 4 parts. Boil together, along with water, until a sample sets to the consistency of plaster, the mixture being then thinned down with oil of turpentine while still warm.

3.—Driving-Belt Grease.—Linseed oil, 45 parts; litharge, 20 parts; water, 20 parts. These three substances are boiled together until the mass has assumed the consistency of plaster, and is thinned to about the same degree of fluidity as varnish, by adding oil of turpentine in the warm.

Cart Grease

Palm-Oil Cart Grease.—Palm oil, 210 parts; tallow, 85 parts; soda lye, 65 parts; water, 920 parts. The palm oil and tallow are melted together, the mixture rendered uniform by stirring, and the soda lye added. The density of the latter should be 20 to 21° Bé.; that is to say, the Baumé aerometer should sink into the solution down to the 20 or 21° mark on the scale. After the soda lye has been stirred in the water is added, and the mass is stirred until uniform, whereupon it is ladled out into vessels to set.

Chain Lubricant

A mixture of powdered plumbago and glycerine has been warmly recommended at various times as a chain lubricant. Plumbago, 6 parts, mixed intimately with 10 parts of petrolatum, also yields a satisfactory lubricant.

Clockmakers' Oils

Mineral Oil for Clockmakers' Use.—The mineral oil for clockmakers' use is a specially refined heavy tar oil. One hundred parts of ordinary heavy tar oil are treated with 2 parts of bleaching powder, well stirred in, and followed by 3 parts of crude hydrochloric acid. The mixture must then be vigorously stirred, and set aside for 6 hours. At the end of this time the oil is poured off from the watery liquid, and repeatedly shaken up with 5 parts of caustic soda lye each time. Finally, the refined oil is filtered through gray blotting paper.

Olive Oil for Clockmakers' Use.—To prepare this lubricant, an olive oil must be taken that has been refined by the sulphuric-acid method, very well known, and afterward shaken up with about 2% of weak lye to insure the complete elimination of the final traces of free acid. The oil and lye are left in contact for several days after a thorough shaking the oil floating on the surface being then drawn off and bleached with spirits, as described above. Like all other fine lubricating oils, the olive oil so treated must be filled into small bottles, which are then tightly corked, and stored with care.

Cycle Oil

1.—This is commonly made up of sperm oil and vaseline, 3 parts of the former to 1 part of the latter, by weight. A greater quantity of vaseline could be used, and some mineral oil as a thinning agent.

2.—Cycle-Chain Lubricant.—a.—Melt some tallow, then stir in powdered plumbago (graphite or black lead) until it is thick enough to set solid when cold. While fluid pour it into molds.

b.—The foregoing recipe applies to blocks of hard lubricant that is rubbed on the chain. If the chain can be soaked and stirred about in the fluid mixture, it is much better.

c.—Mix plumbago and vaseline to a stiff consistency. This does not set, but is applied with a brush.

Cylinder Oil

Filtered cylinder oil, 3 parts; black cylinder oil, 2 parts; thickened rape oil, 1 part. Heat to 200° F. in a steam-jacketed pan for half an hour, stirring well, When settled, it can be run into barrels while warm. If desired, half the rape oil can be omitted and this quantity of lard oil added. What is known as A and B blend consists of 9 parts of steam-refined cylinder oil, 3 parts of thickened rape oil and 3 parts of lard oil. This is A blend. The B blend consists of 9, 4 and 4 parts, respectively.

Drill Lubricator

For drilling wrought iron, use 1½ lb. of soft soap mixed with 1½ gal. of boiling water. Insures ease in working, and clean cutting.

Gear and Pinion Grease

The Detroit United Railways is using on its cars a gear and pinion "dope" grease that is giving very satisfactory service. Through its use the cost of lubricating gears has been reduced 56 to

80 cents per 1,000 miles, and the cost of lubricating pinions 32 to 40 cents per 1,000 miles. About 25 lb. of the lubricant is packed in each gear case. The ingredients and the proportions used in mixing this dope are as follows: Animal fat (tallow and lard), 18%; oleic acid, 3%; lime, 3%; Dixon's best graphite, 8%; special paraffine stock, 48%; 650 fire cylinder stock, extremely viscous, 20%.

Hemp Ropes

Cut a quantity of tallow into small pieces, and place the latter in a clean vessel on a moderate fire. When melted, run the liquid fat through a wire sieve into another vessel, in which mix, with constant stirring, 1-5 part, by weight, of hot linseed-oil varnish, taking care that it is thoroughly incorporated. To this mixture add 1-15 part of vaseline. After cooling, this grease is applied by means of a wooden spatula on the rope, and rubbed in with a clean woolen rag. The grease should preferably be lukewarm when rubbed in.

Machine Oils and Solid Greases, American

A number of these products have been found, on careful examination, to possess the following composition:

1.—Oleic acid, 90 parts; petroleum, 10 parts.

2.—Oleic acid, 100 parts, glycerine, 50 parts.

3.—Oleic acid, 100 parts; guaiacum oil, 20 parts.

4.—Glycerine, 100 parts; petroleum, 10 parts.

5.—Glycerine, 100 parts; olive oil, 50 parts.

6.—Gamber fat, 100 parts; coal tar, 30 parts.

Machinery Lubricants

1.—Graphite, 28 parts; talc, 20 parts; sulphur, 16 parts; wax or paraffine, 16 parts.

2.—Graphite, 15 parts; bone glue, 7½ parts; water, 16 parts; sulphur, 6 parts; wax or paraffine, 5½ parts. A patent has been taken out in France for lubricants compounded in this manner.

3.—Chard's Preparation for Heavy Bearings consists of: Petroleum (gravity 25°), 12 oz.; caoutchouc, 2 oz.; sulphur 2 oz.; plumbago, 4 oz.; beeswax, 4 oz.; sal soda, 2 oz. The composition is stirred and heated to 140° F. for half an hour.

4.—Booth's.—Soda, ½ lb.; rape-seed oil, 1 gal.; water, 1 gal.; tallow or palm oil, ½ lb.; mix intimately, heat to boiling, and continue stirring till cooled down to 60 to 70° F. (15½ to 21° C.).

Piston-rod Grease

Paraffine, 1 part; powdered talc, 4 parts, are stirred together whilst hot, wicks are then dipped in the mixture, and are afterwards pressed into position in the piston-rod gland. This lubricant will grease a piston-rod for 8 to 14 days with one application.

Sewing Machine Oil

1.—A mixture of: Olive oil, 3 parts; almond oil, 2 parts; rape oil, 1 part, is treated with alcohol as already described. This mixed lubricant is fairly fluid, and is therefore admirably suited for oiling very fine machine parts.

2.—Best.—Pale oil of almonds, 9 oz.; rectified benzoline, 3 oz.; foreign oil of lavender, 1 oz. Mix and filter.

3.—Common.—Petroleum, 3 oz.; pale nut oil, 9 oz.; essential oil of almonds, 40 to 50 drops. Mix and filter.

4.—The writer was given a simple recipe of 2 parts of sperm oil and 1 part petroleum. He made a quart of this for domestic use, and it answered excellently. Through not having great use for it, the quantity made was not finished for about 12 years, and at the expiration of this time the oil was as good as at first, though a little darker in color.

5.—Sperm oil, to which a little kerosene oil has been added, makes a very satisfactory lubricant for sewing machines and other light machinery.

6.—Soft paraffine, 1 part; paraffine oil, 7 parts. Melt the soft paraffine and add the oil. Allow to stand for some hours, and then pour off the liquid.

Watch Oils (See also **Clockmakers' Oils**)

An oil fit to be used as a lubricator for fine mechanism should possess the following essential qualities: It should neither thicken or dry up nor get hard at a low temperature, nor should it be subject to oxidation. In spite of the vast progress natural science has made of late years, it has not succeeded in discovering an animal or vegetable oil possessing these combined properties without previous artificial manipulation. Let us mention a few instances:

1.—Almond oil has the valuable property of not becoming firm till below 17° R., but it oxidizes sooner than any other oil.

2.—Poppy seed and oil will withstand cold to 15° R. and preserves itself well

from oxidation, but it is one of the drying oils and therefore useless as a watch oil.

3.—Olive oil, up to the present the most useful among watch oils, does not dry or thicken, nor does it oxidate for a comparatively long time, but it hardens at 2° R.

4.—The properties of neatsfoot oil are similar to those of olive oil, but it exceeds the latter in resistance against oxidation.

Wire Ropeways

1.—Tar, 100 parts; brewer's pitch, 100 parts; colophony, 25 parts; train oil, 10 to 25 parts, are melted together and stirred until the mass is cold.

2.—For the lubrication of wire ropes use a mixture of mica, axle grease, tar, and summer oil. According to the *Engineering and Mining Journal* this is unpatented, and can be made of any desired consistency. The tar and oil must be free from acid. It is claimed that it thoroughly penetrates between the wires, prevents rust, and fills the cable, resists water, does not strip, and is very economical if added sparingly, as all lubricants should be, after the first dose. It goes without saying that cables well taken care of will last very much longer than neglected ones; besides which, there is the far more important matter of safety in mine hoists to be considered, one condition of this being the clean state of the interior wire surfaces.

Wood, Lubricants for

1.—Wood screws or any wood surfaces that rub can be successfully lubricated with plain plumbago (black lead). It can be applied mixed with water to the consistency of paint, or it will do if it can be dusted on dry.

2.—To a quantity of good lard, rendered semi-fluid (but not liquid) by gentle heat in an iron pan, is gradually added 1-5 part by weight of finely powdered and sifted graphite (black lead), with careful and continued stirring until the mass is homogeneous and smooth: the heat is then steadily increased till the compound liquefies, when it is allowed to cool, the stirring having been meanwhile kept up unceasingly.

3.—Tallow, 8 lb.; palm oil, 10 lb.; graphite (black lead), 1 lb.

4.—Lard, 2½ lb.; camphor, 1 oz.; graphite (black lead), ½ lb. Rub up the camphor into a paste with part of the lard in a mortar, add the graphite and the rest of the lard, and intimately mix.

CHAPTER IX.

PAINTS, VARNISHES, BRONZING, LACQUERS, STAINS, SIZES, DRIERS, WHITEWASHES, ETC.

BRIEF SCHEME OF CLASSIFICATION

BRONZING	PAINTS
ENAMEL PAINTS	SIZE
FILLERS	VARNISHES
JAPANS AND JAPANNING	WHITEWASH
LACQUERS AND LACQUERING	

The subject of paints, pigments, varnishes, japans and lacquers offers peculiar difficulties when it comes to classification. Where does a varnish begin and a lacquer end? This is a question which is almost impossible to answer. The classification in this book is based on certain well-known distinctions and is perhaps sufficiently accurate for the ordinary user. A series of definitions from the Century Dictionary may, however, not come amiss, but as has already been remarked, the line of demarkation between the various classes of paints, etc., is not well marked.

Drier.—Any substance added to a paint to increase its drying qualities. It may be a liquid, such as japan, or a dry material, as oxide of lead, oxide of manganese, burnt umber or sugar of lead.

Japan.—A liquid having somewhat the nature of a varnish, made by cooking gum shellac with linseed oil in a varnish kettle. Litharge or some similar material is also usually added to quicken the drying of the resulting japan.

Lacquer.—An opaque varnish containing lac, properly so called. Especially the kind of varnish consisting of shellac dissolved in alcohol, with the aid of other ingredients, particularly coloring matters. It is also applied to different materials to protect them from tarnishing and to give them luster, especially to brass.

Paint.—A substance used in painting, composed of a dry coloring material intimately mixed with a liquid vehicle. It differs from a dye in that it is not designed to sink into the substance to which it is applied, but to form a superficial coating.

Pigment.—Any substance that is or can be used by painters to impart color to bodies; technically, a dry substance usually in the form of powder or in lumps so lightly held together as to be easily pulverized, which, after it has been mixed with a liquid medium can be applied by painters to surfaces to be colored. Pigment is properly restricted to the dry coloring matter which, when mixed with a vehicle, becomes a paint, but the two words are commonly used without discrimination.

Siccative.—In painting, any material added to an oil paint to hasten the drying of the oil; a dryer. Siccative is more of a book word, dryer being the term commonly used by painters.

Stain.—To color by a process other than painting or coating or covering the surface. (a) To color (as glass) by something which combines chemically with a substance to be colored. (b) To color by the use of a thin liquid which penetrates the material, as in dyeing cloth or staining wool.

Varnish.—A solution of resinous matter, forming a clear, limpid fluid capable of hardening without losing its transency; used by painters, gilders, cabinet makers and others for coating over the surface of their work in order to give it a shining, transparent and hard surface, capable of resisting, in a greater or less degree, the influences of air and moisture.

BRONZING

1.—Copper powder is obtained by saturating nitrous acid with copper, and then precipitating the copper by exposing iron bars in the solution.

2.—Dutch foil, reduced to a powder by grinding, is also used, and powdered plumbago gives an iron-colored shade.

3.—Another kind is made from verdigris, 8 parts; putty powder, 4 parts; borax, 2 parts; bichloride of mercury, ¼ part; grind into a paste with oil and fuse them together.

4.—Another (red): Sulph. copper, 100 parts; carb. soda, 60 parts; mix and incorporate by heat; cool, powder, and add copper filings, 15 parts; mix; keep at a white heat for 20 minutes; cool, powder, wash and dry.

Banana Oil for Bronzing Solutions.—This oil, so named on account of the odor imparted by its amyl acetate constituent, seems to have no definite formula, but to vary in composition according to the ideas of those who prepare it. This is usually a mixture of equal parts of amyl acetate, acetone and benzine, with just enough pyroxylin dissolved therein to give the finished product sufficient body and to leave a protective covering after the liquids have evaporated. A solution of 1 gram of celluloid in 25 c. c. of amyl acetate is sometimes sold for banana oil. This "oil" and its vapor, it should be remembered, are quite inflammable.

Gold Paint.—1.—Do not mix the gold size and powder together, but go over the article to be gilded with the size alone, giving an even and moderate coating. Let it dry, which will not take long, till it is just sticky, or, as gilders call it, tacky. Then over a sheet of smooth writing paper dust on the dry gold powder by means of a stout, soft, sable brush.

2.—Bisulphide of tin has a golden luster, flaky texture, and is used for ornamental work, such as paper hangings, and as a substitute for gold leaf.

3.—Gold Bronze Powder.—a.—Pure gold bronze powder may be made as follows: Grind leaf gold with pure honey until the leaves are broken up and minutely divided. Remove this mixture from the stone by a spatula and stir up in a basin of water; the water will melt the honey and set the gold free. Leave the basin undisturbed until the gold subsides. Pour off the water and add fresh instead, until the honey is entirely washed away, after which collect the gold on filtering pans and dry for use. b.—A cheaper sort may be made thus: Melt 1 lb. of tin in a crucible and pour it on ½ lb. of pure mercury; when this is solid grind it into powder with 7 oz. of flowers of sulphur and ½ lb. of sal ammoniac.

4.—Gold Enamel Paints.—The "greening" of the vehicle, which is very objectionable and unsightly, is set up by free acid in the medium, and as these bronzes are very readily attacked by acids, this is the reason of this greenish appearance developing, as chemical reaction takes place. It may be overcome by neutralizing any acid in the liquid used as a binder by the addition of lime, etc., as in the Bessemer paint.

DRIERS

There are several kinds of driers, but the best usually have litharge or sugar of lead as the important "drying" agent. Litharge is best for dark and middle tints, while sugar of lead is better suited for light tints.

1.—For a liquid drier, boil 1 qt. of linseed oil for 1 hour with 1 lb. finely powdered binoxide of manganese. For a solid drier use borate of manganese in powder, or mixed with oil.

2.—A good drier for paints is made by grinding or dissolving a small quantity of sugar of lead in linseed oil.

3.—Drier for Oil Colors and Varnishes.—Water, 100 parts; gum lac, 12 parts; borax, 4 parts.

4.—Driers (Painters'). — Litharge (best) ground to a paste, with drying oil. For dark colors.

5.—White copperas and drying oil. As the last.

6.—Sugar of lead and drying oil. The last two are for pale colors.

7.—White copperas and sugar of lead, of each 1 lb.; pure white lead, 2 lb. For "whites," and opaque light colors, grays, etc. Driers are employed, as the name implies, to increase the drying and hardening properties of oil paints. A little is beat up with them at the time of mixing them with the oil of turpentine for use.

FILLERS FOR WOOD

1.—Take equal parts of japan, boiled linseed oil and turpentine, and half that quantity of starch. Mix thoroughly, and apply with a sponge or flannel. When the polish is for walnut, a little burnt umber is added to the solution, and a little Venetian red when for cherry wood.

2.—American Wood Filler.—Apply to the wood with a brush the following mixture: Pulverized starch, by weight, 3 parts; heavy spar, 3 parts, ½ by weight of siccative, with enough turpentine to make of the consistency of ordinary varnish. For dark woods add to the siccative, umber up to ½ part. Rub across the grain of the wood with a piece of felt fastened to a piece of wood. Let the wood dry about 8 hours, rub with glass paper, then polish and varnish.

3.—Filling for Cracks.—A very complete filling for open cracks in floors may be made by thoroughly soaking newspapers in paste made of 1 lb. of flour, 3 qt. of water and 1 tablespoonful of alum, thoroughly boiled and mixed. Make the

final mixture about as thick as putty, and it will harden like papier mâché. This paper may be used for molds for various purposes.

4.—German Wood Filling.—Fill the pores of the wood with new tallow and plaster of paris, well amalgamated before a fire, if the weather is cold. Darken, if required, with any coloring to suit. When well rubbed in, give a coat of shellac and French polish or varnish.

JAPANS AND JAPANNING

When finished, wood, papier mâché, composition or materials are varnished in the usual manner and left to dry in the air, the drying is, in most cases, imperfect, and the coating more or less uneven. If the surface thus varnished is heated for some time to a temperature of from 250 to 300° F., or higher, it is found that the whole of the solvent or vehicle of the gums or rosins in the varnish is soon driven off, and the gummy residue becomes liquefied or semi-liquefied, in which state it adapts itself to all inequalities, and, if the coating is thick enough, presents a uniform glossy surface, which it retains on cooling. This process of drying out and fusion secures a firm contact and adhesion of the gums or rosins to the surface of the substance varnished, and greatly increases the density of the coating, which enables it to resist wear and retain its gloss longer. This process of hardening and finishing varnished or lacquered work by the aid of heat constitutes the chief feature of the japanner's art. In practice, the work to be japanned is first thoroughly cleansed and dried. If of wood, composition, or other porous material, it is given, while warm, several coats of wood filler, or whiting mixed up with a rather thin glue size, and is, when this is hardened, rubbed down smooth with pumice stone. It is then ready for the japan grounds. Metals, as a rule, require no special preparation, receiving the grounds directly on the clean, dry surface. In japanning, wood and similar substances require a much lower degree of heat, and usually a longer exposure in the oven than metals, and again a higher temperature may be advantageously employed when the japan is dark than when light-colored grounds are used; so that a definite knowledge of just how much heat can be safely applied, and how long an exposure is required with different substances and different grounds can only be acquired by practical experience. Large japanners seldom make their own varnishes, as they can procure them more cheaply from the varnish maker. The japanner's oven is usually a room, or large box, constructed of sheet metal, and heated by stove drums or flues, so that the temperature—which is indicated by a thermometer or pyrometer hung up inside, or with its stem passing through the side wall midway between the top and bottom of the chamber—can be readily regulated by dampers. The ovens are also provided with a chimney to carry off the vapors derived from the drying varnish, a small door through which the work can be entered and removed, and wire shelves and hooks for its support in the chamber. The ovens must be kept perfectly free from dust, smoke and moisture. A good cheap priming varnish for work to be japanned consists of pale shellac, 2 oz.; pale rosin, 2 oz.; rectified spirit, 1 pt. Two or three coats of this are put on the work in a warm, dry room. A good background is prepared by grinding fine ivory black with a sufficient quantity of alcoholic shellac varnish on a stone slab with a muller until a perfectly smooth black varnish is obtained. If other colors are required, the clear varnish is mixed and ground with the proper quantity of suitable pigments, in a similar manner; for red, vermilion or Indian red; green, chrome green or Prussian blue and chrome yellow; blue, Prussian blue, ultramarine or indigo; yellow, chrome yellow, etc. But black is the hue commonly required.

Applications.—From 1 to 6 or more coats of varnish are applied to work in japanning, each coat being hardened in the oven before the next is put on. The last coat in colored work is usually of clear varnish, without coloring matters, and is, in fine work, sometimes finished with rotten stone and chamois. For ordinary work, the gloss developed in the oven, under favorable conditions, is sufficient.

Black.—1.—Asphaltum, 3 oz.; boiled oil, 4 qt.; burnt umber, 8 oz. Mix by heat, and, when cooling, thin with turpentine.

2.—Amber, 12 oz.; asphaltum, 2 oz.; fuse by heat, and add boiled oil, ½ pt.; rosin, 2 oz.; when cooling, add 16 oz. of oil of turpentine. Both are used to varnish metals.

3.—Mix shellac varnish with either ivory black or lampblack, but the former is preferable. These may be always laid on with the shellac varnish, and have their upper or polishing coats of common seed lac varnish.

4.—A common black japan may be made by painting a piece of work with drying oil and putting the work into a

stove, not too hot, but of such a degree as will change the oil black without burning it, gradually raising the heat and keeping it up a long time. This requires no polishing.

5.—Asphaltum, ½ lb.; melt; then add hot balsam of capivi, 1 lb.; and when mixed, thin with hot oil of turpentine.

6.—Grind lampblack very smooth on a marble slab, with a muller, with turpentine, and then add copal varnish to the proper consistency.

7.—For Leather.—Burnt umber, 4 oz.; true asphaltum, 2 oz.; boiled oil, 2 qt. Dissolve the asphaltum by heat in a little of the oil, add the burnt umber, ground in oil, and the remainder of the oil; mix, cool, and thin with turpentine. Flexible.

LACQUERS AND LACQUERING

Materials for Lacquering.—The lacquer = shellac + alcohol. Other substances: A, spirits of turpentine, turpentine varnish, mastic varnish, Canada balsam; B, pyroacetic ether; C = red, dragon's blood, annatto, red sanders; D = yellow, turmeric, gamboge, saffron, sandarac, cape aloes.

Directions for Making.—Mix the ingredients, and let the vessel containing them stand in the sun, or in a place slightly warmed, 3 or 4 days, shaking it frequently till the gum is dissolved, after which let it settle from 24 to 48 hours, when the clear liquid may be poured off for use. Pulverized glass is sometimes used in making lacquer, to carry down the impurities.

TABLES OF LACQUERS.

	Solutions.								Reds.			Yellows.					
	Shellac.	Mastic.	Canada Balsam.	Alcohol.	Pyro-acetic Ether.	Spirits of Turpentine.	Turpentine Varnish.	Simple Pale Lacquer.	Dragon's Blood.	Annatto.	Sanders.	Turmeric.	Gamboge.	Saffron.	Cape Aloes.	Sandarac.	
No.	oz.	dr.	dr.	pt.	oz.	dr.	oz.	pt.	dr.	dr.	gr.	dr.	dr.	dr.	dr.	dr.	
1	4	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	Strong simple.
2	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	Simple pale.
3	1	...	...	1	...	...	...	...	...	...	...	...	1	...	3	...	Fine pale.
4	1	...	...	1	...	...	...	...	...	...	...	1	1	2	...	...	Fine pale.
5	1	...	...	2	...	...	...	...	1	1	...	...	16	4	...	8	Fine pale.
6	2	...	...	2	...	...	...	...	1	8	...	32	...	...	...	8	Pale gold.
7	2	...	...	1	...	...	...	...	...	...	...	...	2	...	4	...	Pale yellow.
8	5	...	...	3	30	...	...	...	...	...	...	...	5	...	...	...	Pale yellow—(Ross's.)
9	...	...	...	...	...	...	...	1	...	1	...	4	...	...	...	...	Full yellow.
10	3	...	...	1	...	...	...	...	...	2	...	16	...	2	...	...	Gold.
11	3	...	...	4	...	...	6	...	...	...	...	64	6	...	...	14	Gold.
12	1	...	...	1	...	...	...	...	...	...	...	20	...	...	2	5	Gold.
13	3	...	...	1	...	...	...	...	4	...	...	16	...	...	...	...	Deep gold.
14	3	...	...	1	...	...	...	...	4	...	...	1	...	...	...	...	Deep gold.
15	3	...	...	1	...	30	...	...	40	...	12	10	...	...	...	...	Deep gold.
16	...	...	...	...	...	...	...	1	8	32	...	...	...	...	...	...	Red.
17	1	...	...	...	...	...	1	...	8	24	...	...	...	...	...	27	Red.
18	15	30	30	6	...	...	...	...	20	...	...	60	...	10	...	...	Tin lacquer.
19	...	...	...	...	...	...	...	1	...	...	...	4	1	...	...	...	Green, for bronze.

The union of red with yellow produces a fine orange color. dr. = drachm; gr. = grain.

Brass

1.—Be sure there is no oil or grease on the brass; do not touch the work with the fingers; hold it with spring tongs or a taper stick in some of the holes.

2.—Always handle with a piece of clean cloth.

3.—Heat the work so hot that the brush will smoke when applied, but avoid overheating, as it burns the lacquer.

4.—It is well to fasten a small wire across the lacquer cup, from side to side, to scrape any superfluous lacquer. The

brush should have the ends of the hairs all exactly even. If not so, trim the ends with sharp scissors.

5.—Scrape the brush as dry as possible on the wire, making a flat, smooth point at the same time.

6.—Use the very tip of the brush to lacquer with, and carry a steady hand.

7.—Put on at least 2 coats. It is well (to make a very durable coat) to blaze off after each coat with a spirit lamp or Bunsen burner, taking care not to overheat and burn the lacquer.

8.—If the lacquer is too thick it will look gummy on the work. If too thin, it will show prismatic colors. In the first case add a little alcohol; in the latter, set the cup on the stove and evaporate some.

9.—A good deal of cheap work, like lamp burners, is dipped. Use a bath of nitric and sulphuric acids, equal parts; dip work, hung on wire, into acid for a moment; remove, rinse in cold water thoroughly; dip in hot water, remove, put in alcohol, rinse around, then dip momentarily in a lacquer, shaking vigorously on removing, to throw off extra lacquer, and lay on a warm metal plate till dry; let cool, and it is done.

10.—Avoid handling lacquered work until cold.

Lacquers for Brass.—1.—Seed lac, dragon's blood, annatto and gamboge, of each 4 oz.; saffron, 1 oz.; alcohol, 10 pt.

2.—Turmeric, 1 lb.; annatto, 2 oz.; shellac and gum juniper, each 12 oz.; alcohol, 12 oz.

3.—Seed lac, 6 oz.; dragon's blood, 40 gr.; amber and copal, triturated in a mortar, 2 oz.; extract of red sanders, ½ dr.; Oriental saffron, 36 gr.; coarsely powdered glass, 4 oz.; absolute alcohol, 40 oz. Very fine.

4.—Seed lac, 3 oz.; amber and gamboge, each 2 oz.; extract of red sanders, ½ dr.; dargon's blood, 1 dr.; saffron, ½ dr.; alcohol, 2 pt. 4 oz.

5.—Turmeric, 6 dr.; saffron, 15 gr.; hot alcohol, 1 pt.; draw the tincture, and add gamboge, 6 dr.; gum sandrac and gum elemi, each 2 oz.; dragon's blood and seed lac, each 1 oz.

6.—Alcohol, 1 pt.; turmeric, 1 oz.; annatto and saffron, each 2 dr. Agitate frequently for a week, filter into a clean bottle, and add seed lac, 3 oz. Let stand, with occasional agitation, for about 2 weeks.

7.—Gamboge, ½ oz.; aloes, 1½ oz.; fine shellac, 8 oz.; alcohol, 1 gal.

8.—Put 3 oz. of seed lac, 2 dr. of dragon's blood and 1 oz. of turmeric powder into 1 pt. of alcohol. Let the whole remain for 14 days, but during that time agitate the bottle once a day at least. When properly combined, strain the liquid through muslin, when it is ready for use.

9.—To 5 oz. of alcohol add gamboge enough to give a bright yellow color, and 3 oz. of seed lac in fine powder. Put in a sand bath till dissolved.

10.—Ground turmeric, as sold, 1 oz.; saffron and Spanish annatto, each 2 dr.; highly rectified alcohol, 1 pt. Place them in a moderate heat, shaking occasionally, for several days; then add 3 oz. of good seed lac, roughly powdered; shake occasionally until the lac is dissolved. If a deep orange lacquer is required, increase the quantity of annatto; if a bright yellow, decrease it. Lay it on with a brush (warm), like you would paint. One or more coats, if necessary. Avoid using too much seed lac, as it has a tendency to prevent the lacquer lying evenly.

11.—Pale gold lacquer is best for microscope; be sure and get the best quality, and see that the things are sufficiently hot before putting on the lacquer; heat after lacquering, and it will stand well. Damp will affect the best lacquering.

12.—No. 3 is best for optical work. If it comes off, either the metal was not clean, when applied, or else it was put on cold. The metal should be heated to just such a point that it dries as fast as the brush paces over it. Work is often spoiled in lacquering. Circular things may be done in the lathe, going quite slow, and working a good body by going around several times.

13.—Bronzed Brass.—To 1 pt. of the above lacquer add gamboge, 1 oz.; and after mixing it add an equal quantity of the first lacquer.

14.—Dipped Brass.—Alcohol, proof specific gravity not less than 95-100, 2 gal.; seed lac, 1 lb.; gum copal, 1 oz.; English saffron, 1 oz.; annatto, 1 oz.

15.—Gold-Colored Lacquer for Dipped Brass.—Alcohol, 36 oz.; seed lac, 6 oz.; amber, 2 oz.; gum gutta, 2 oz.; red sandalwood, 24 gr.; dragon's blood, 60 gr.; Oriental saffron, 36 gr.; pulverized glass, 4 oz.

16.—Gold-Colored Lacquer for Brass Not Dipped.—Alcohol, 4 gal.; turmeric, 3 lb.; gamboge, 3 oz.; gum sandrac, 7 lb.; shellac, 1½ lb.; turpentine varnish, 1 pt.

17.—Gold-Colored Lacquer for Brass Watch Cases, etc.—Seed lac, 6 oz.; amber, 2 oz.; gamboge, 2 oz.; extract of red sanders wood in water, 24 gr.; dragon's blood, 60 gr.; oriental saffron, 36 gr.; powdered glass, 4 oz.; pure alcohol, 36 oz. The seed lac, amber, gamboge and dragon's blood must be pounded very fine

on porphyry or clean marble, and mixed with the pounded glass. Over this mixture is poured the tincture formed by infusing the saffron and the sanders wood extract in the alcohol for 24 hours, then straining. Metallic articles that are to be covered with this varnish are heated, and, if they admit of it, immersed in packets.

18.—For philosophical instruments: Gamboge, 1½ oz.; sandarac, 4 oz.; elemi, 4 oz.; best dragon's blood, 2 oz.; terra merita (terra merita is the root of an Indian plant; it is of a red color, and much used in dyeing; in varnishing, it is only employed in the form of a tincture, and is particularly well adapted for the mixture of those coloring parts which contribute the most toward giving metals the color of gold; in choosing it, be careful to observe that it is sound and compact), 1½ oz.; Oriental saffron, 4 gr.; seed lac, 2 oz.; pounded glass, 6 oz.; pure alcohol, 40 oz. The dragon's blood, gum elemi, seed lac and gamboge are all pounded and mixed with the glass. Over them is poured the tincture obtained by infusing the saffron and terra merita in the alcohol for 24 hours. This tincture, before being poured over the dragon's blood, etc., should be strained through a piece of clean linen cloth and strongly squeezed. If the dragon's blood gives too high a color the quantity may be lessened, according to circumstances. The same is the case with the other coloring matters. This lacquer has a very good effect when applied to many cast or molded articles used in ornamenting furniture.

Bronze Lacquers.—1.—To make a bronze lacquer, dissolve ¾ lb. of shellac and ½ lb. of sandarac in 3 qt. of alcohol, and add enough extract of dragon's blood and turmeric to produce the desired color.

2.—For ornaments bronzed with gold-colored bronze, paint the articles, of cast iron, with white paint, which is white lead and oil; when hard dry, varnish with copal varnish; when sticky dry, dust the bronze powder over it; and when hard dry, brush off all the superfluous bronze with a camel's-hair brush. To protect it from the dust and from soiling, coat the bronze surface, when thoroughly dry, with spirit copal varnish.

Color for Lacquer.—Alcohol, 1 pt.; annatto, 2 oz.

Colorless Lacquer.—1.—For a colorless lacquer, dissolve bleached shellac in pure alcohol, settle, and decant. Make the lacquer very thin. The usual lacquer for brass is made with ordinary shellac and alcohol, made very thin, settled, and decanted.

2.—Mastic, 5 parts; amber, 5 parts; sandarac, 10 parts; shellac, 10 parts; alcohol, 100 parts.

Copper.—Mastic, 8 parts; camphor, 6 parts; sandarac, 15 parts; bleached shellac, 15 parts; alcohol, 40 parts.

Green Lacquer.—1.—Turmeric, 18 oz.; shellac, 15 oz.; gum sandarac, 1 oz.; gum elemi, 3 oz.; gamboge, 3 oz.; methylated spirits, 3 gal.; expose to a gentle heat; after straining, add 1½ gal. of spirit to the sediment, and treat as before.

2.—Mix 5 oz. of shellac, 6 oz. of turmeric, 4 oz. of gum sandarac and 1 oz. each of gum elemi and gum gamboge in 1 gal. methylated spirits; expose to gentle heat, strain, add ½ gal. of spirit to the sediment, and treat as before.

Iron, Lacquer for.—1.—Asphaltum, 10 parts; rosin, 3 parts; lampblack, 1 part; petroleum, 25 parts.

2.—Amber, 12 parts; turpentine, 12 parts; rosin, 2 parts; asphaltum, 2 parts; drying oil, 6 parts.

3.—Asphaltum, 3 lb.; shellac, ½ lb.; turpentine, 1 gal.

Sheet Metal, Lacquer for.—Asphaltum, 5 parts; colophony, 3 parts; oil of turpentine varnish, 10 parts; oil of turpentine, 14 parts.

Steel, Lacquer for.—Pure mastic, 8 parts; camphor, 4 parts; sandarac, 12 parts; elemi, 4 parts. Dissolve in pure alcohol; filter. Use the lacquer cold. It will be clear and transparent when dry.

Tin Plate, Lacquer for.—1.—Alcohol, 12 oz.; turmeric, 6 dr.; saffron, 3 scruples; sandarac, 3 dr.; Canada balsam, 3 dr.; mastic, 3 dr. When dissolved, add oil of turpentine, 120 minims.

2.—Alcohol, 1 qt.; shellac, 4 oz.; red sanders, 1 oz.; turmeric, 2 oz. Shake frequently for 24 hours, and bottle. Various colors can be given to the lacquer by adding Prussian blue, lakes, etc.

Tinfoil, Lacquer for.—Alcohol, 1½ qt.; shellac, 10½ oz. Dissolve the shellac in the alcohol and filter. Prevent the evaporation of the alcohol as much as possible. Add to this shellac varnish, 5¼ oz. best white gum elemi and 21 dr. Venetian turpentine. Let this mixture stand in a warm place; stir it frequently. Filter; press out the remainder, and add to the filtrate. This varnish may be colored if desired.

Tools, Lacquer for.—The tools must be cleaned and polished so as to be absolutely free from grease. They are next slightly warmed and varnished with a solution of seed lac or shellac in alcohol. The success of the operation depends on the

clearness of the surface. A finger touch before varnishing will affect the finish.

Transparent Lacquer.—Powdered gum sandarac, 4 parts; turpentine, 7 parts; spirit of turpentine, 28 parts. Dissolve the turpentine and the powdered gum sandarac over a water bath, in the spirit of turpentine. Before this varnish is used the bottle should be exposed to the sun for about an hour.

Zinc, Lacquer for.—A good lacquer consists of: Alcohol, 8 oz.; gamboge, 1 oz.; shellac, 3 oz.; annatto, 1 oz.; solution of 3 oz. of seed lac in 1 pt. of alcohol. When dissolved add ¼ oz. of Venice turpentine and ¼ oz. of dragon's blood to make it dark. Keep in a warm place for 4 or 5 days.

PAINTS

Aluminum Paint

Aluminum, when reduced to fine powder and mixed with a solution of gum lac in water, gives a metallic paint which covers well, and which may be tinted with aniline dies soluble in water. The solution of lac is made as follows: Soda crystals, 8 oz.; borax, 8 oz.; gum lac, 2 lb.; water, 1 gal. Boil the water and soda crystals and borax together, then add the lac, keep boiling till lac is dissolved. If this solution comes too thick, add more water and borax (1 oz. borax to 1 pt. of water). To this solution, aluminum, finely powdered, is added in sufficient quantity to produce a paint sufficiently fluid to apply with a brush. This paint is brilliant, durable, and impermeable, and is uitable for wood, metals, paper and cloth. If required more elastic add 1 oz. glycerine to every gallon of lac solution.

Anti-corrosion Paint

1.—An Anti-corrosion Paint for Iron. —If 10% of burnt magnesia, or even baryta or strontia, is mixed cold with ordinary linseed oil paint, and then enough mineral oil to develop the alkaline earth, the free acid of the paint will be neutralized, while the iron will be protected by the permanent alkaline action of the paint. Iron to be buried in damp earth may be painted with a mixture of 100 parts of rosin (colophony), 25 of gutta percha, and 50 of paraffine, to which 20 of magnesia and some mineral oil have been added.

2.—Take equal parts by weight of whiting and white lead, with half the quantity of fine sand, gravel, or road dust, and a sufficient quantity of coloring matter. This mixture is made in water and can be used as a water color; but it is more durable to dry it, as cakes or powder, after mixing, and then use it as an oil paint by grinding it again in linseed oil. The preparation of oil recommended for this purpose is: 12 parts by weight of linseed oil; 1 part boiled linseed oil and 3 parts sulphate of lime, well mixed. 1 gal. of this prepared oil is used to 7 lb. of the powder.

Boilers, Paint for

1.—Use asphaltum varnish. There is little or no odor from it when dry.

2.—Coal tar and ground graphite thinned with turpentine make an excellent paint for boiler fronts and pipes in boiler room. The steam pipes for heating should not be painted, or if required, should only have a very thin coat of lampblack and linseed oil. Tin is unfit for roofs of boiler houses. Slate is best. You can make a temporary covering on the tin roof with asphalt and gravel. This will not save the tin, which will soon give out entirely. The cheapest way out of your trouble is to take off the tin and slate the roof.

3.—Rub it over with a mixture of boiled oil and lampblack. From the latter the grease should be taken before mixing by placing it in a flower pot, the top and bottom sealed with clay and subjected to a good heat.

Destroying Paint

Mix 1 part by weight of American pearlash with 3 parts quick stone lime by slaking the lime in water, and then adding the pearlash, making the mixture about the consistency of paint. Lay the above over the whole of the work required to be cleaned with an old brush; let it remain 14 or 16 hours, when the paint can be easily scraped off.

Funnel Paints for Yachts

1.—Zinc white, 98 lb.; China clay, 98 lb.; ultramarine blue, ½ lb.; pale rosin oil, 2 gal.; silicate of soda, 20 gal. Process.—Mix well together and strain. This may be used independently, or with good effects over a previous coat of No. 3 white funnel paint, as the lime will prevent the zinc discoloring.

2.—Back Funnel Paint.—Oxide of manganese, 119 lb.; bone black, 70 lb.; black lead, 10 lb.; rosin oil, 4 gal.; silicate of soda, 20 gal. Process.—As before. All require grinding, and when using should be constantly stirred.

3.—Blue Funnel Paint.—China clay, 189 lb.; ultramarine blue, 30 lb.; pale rosin oil, 4 gal.; silicate of soda, 18 gal. Process.—As before.

4.—Cream Funnel Paint.—White chalk lime, 84 lb.; whiting, 40 lb.; powdered litharge, 196 lb.; pale rosin oil, 4 gal.; silicate of soda, 20 gal. Process.—As before; add the litharge last, mixed with a little water.

5.—Red Funnel Paint, Bright.—White chalk lime, 84 lb.; whiting, 40 lb.; red lead, 196 lb.; pale rosin oil, 4 gal.; silicate of soda, 20 gal. Process.—As before. Should the mixture turn hard on the addition of the red lead, add more rosin oil and stir well in.

Grease Spots, to Kill

Before painting, wash the part with saltpeter, or very thin lime whitewash. If soapsuds are used, they must be washed off thoroughly, as they prevent the paint from drying hard.

Iron, Paints for

A good cheap black paint or varnish for iron work is prepared as follows: Clear (solid) wood tar, 10 lb.; lampblack, or mineral black, 1¼ lb.; oil of turpentine, 5½ qt. The tar is first heated in a large iron pot to boiling, or nearly so, and the heat is continued for about 4 hours. The pot is then removed from fire out of doors, and while still warm, not hot, the turpentine mixed with the black is stirred in. If the varnish is too thick to dry quickly, add more turpentine. Benzine can be used instead of turpentine, but the results are not so good. Asphaltum is preferable to the cheap tar.

Protecting Iron.—Cast-iron water pipes and other articles may be preserved by covering the inside and out with pitch, heated to 300° F. and kept at this point during the dipping. As the material deteriorates after a number of pipes have been dipped, fresh pitch is frequently added, and at least 8% of heavy linseed oil put to it daily; the vessel is also entirely emptied of the pitch and refilled with fresh material, as often as is necessary to insure the perfection of the process. Each casting is kept immersed from thirty to forty-five minutes, or until it attains a temperature of 300° F. After the bath is completed, the castings are removed and placed to drip in such a position that the thickness of the varnish will be uniform. It is essential that the coating be tenacious when cold, and not brittle or disposed to scale off. The pitch or varnish is made from coal tar, distilled until all the naphtha is removed, the material deodorized, and the pitch like wax or very thick molasses.

Tar Paint for Iron Work.—Tar, 191 lb.; sulphur, 7 lb.; red lead, 7 lb.; white lead, 7 lb. Process: Boil together until reduced in bulk one-half.

Magnets, Red Paint Used on

The "paint" used on magnets is usually non-conducting shellac varnish, carrying cinnabar. Try the following formula: Cinnabar, pulverized, 3 parts; Venice turpentine, 2 parts; shellac, pale, 1 part; alcohol, 95%, sufficient. Melt turpentine and shellac, remove from fire, let cool down to about 140° F. and add 10 parts of the alcohol. Rub up the cinnabar with sufficient alcohol to make a paste, and add it to the melted mixture. Put on a water bath for a few minutes, and stir continuously until a smooth, homogeneous fluid is obtained. Remove from fire and stir until cold. Preserve in well-stoppered vials, and when desired for use return to the water bath and heat until the liquid can be applied with a brush. The magnet should be warmed before applying.

Red Oxide of Iron Paints

1.—Bright Red Paint.—Pure bright red oxide, 336 lb.; common barytes, 112 lb.; China clay, 112 lb.; whiting 112 lb.; raw linseed oil, 9 gal.

2.—Specialty Red Oxide Paint for Gasometers, etc.—Red oxide, 392 lb.; barytes, 784 lb.; whiting, 84 lb.; boiled linseed oil, 112 lb.; raw oil, 224 lb.; varnish bottoms, 58 lb.; turpentine, 42 lb.; driers, 224 lb.

3.—Turkey Red Paint.—Pure bright red oxide, 448 lb.; raw linseed oil, 10 gal. A little varnish foots should also be used. Note.—A turkey red (dry) must be a very fine, bright, strong pigment, better than a super-Venetian red.

Stacks, Paint for

1.—Dissolve asphaltum in turpentine with the application of a gentle heat. Use when cold. Apply with a brush.

2.—Paint the stack with thin coal tar mixed with finely ground plumbago. Make of the consistency of ordinary paint.

Stoves, Paint for Sample

Paint the stove with paint made of powdered black lead and linseed oil, and polish in the ordinary way when dry. It may be left out in all kinds of weather without injury to the polish.

Water Paint

Slake any quantity of stone lime by putting it in a tub and covering up to keep in the steam. When slaked pass through a fine sieve, and to each 6 qt. of lime add 1 qt. of rock salt in powder and 1 gal. of water. Boil all together and

skim clean. To each 5 gal. of this liquid add powdered alum, 1 lb.; powdered green copperas, ½ lb.; add very slowly powdered caustic potash, ¾ lb.; fine sand, 4 lbs. Thoroughly mix together and apply with a brush. When dry is as durable as slate, and if used on brick or stone walls will render the latter impervious to wet. For buff use 1 lb. of Oxford ocher to 1 gal. of liquid. For stone use ½ lb. of ocher to 1 gal. of liquid.

Silicate of Soda Water Paint.—The following process will yield good results and will give a paint which may be used as a water or oil paint by thinning with water, or in the ordinary manner by the use of linseed or boiled oil, or it may be mixed ready for use by the addition of the silicate oil substitute. With the exception of blues of the Prussian class, Brunswick greens, and, to some extent, chromes, all colors may be ground with this oil substitute.

Liquid.—1.—Silicate of soda, 45° Beaumé, 112 lb.; pale rosin, 28 lb.; water, 20 gal.

2.—Silicate of soda, 45° Beaumé, 112 lb.; black rosin, 28 lb.; water, 20 gal. Process: Boil the water and silicate of soda together, and, while boiling, sift in the rosin, which should be coarsely powdered, stirring all the while. Boil till the rosin is dissolved, then strain through coarse canvas.

Waterproof Water Paint

A waterproof paint may be made by dissolving in 2 qt. of water 1 lb. brown soap and then adding 6 qt. boiled oil and 1 oz. vitriol. After removing from the fire, add 2 qt. turpentine with any color it is desired to mix with it. Strain well and thin with turpentine.

Black Waterproof Paint. — Carbon black, 10 lb.; Paris white, 90 lb.; barytes, 60 lb.; litharge, 21 lb.; white lead, 21 lb.; soft soap, 17 lb.; boiled oil, 10 lb.; raw linseed oil, 10 lb.; water, 100 lb. May also contain varnish.

Elastic Waterproof Paint.—1.—There are a large number of mixtures used as bases for these paints, but it depends really upon the ultimate or special use of the paint when deciding upon a medium. The following makes suitable application for horse, rick and sail cloths, tents, shop blinds, etc. It will dry fairly quickly and the coating will prove efficient for quite a considerable period, but two or even three coats should be laid on, and then the resistance to wet will endure as long as the fabric of the sheet itself. Any other color would be produced by substituting the pigment desired for that in the recipe.

2.—Black.—Boiled oil, 5 gal.; turps, 4 gal.; bone black, 17 lb.; yellow soap, 2½ lb.; Chinese blue, 1 lb.

Zinc

To Prepare for Painting.—Dissolve 1 part of chloride of copper, 1 part of nitrate of copper and 1 part of sal ammoniac in 64 parts of water and add 1 part of commercial hydrochloric acid. Brush the zinc over with this, which gives it a deep black. Leave to dry 24 hours, when any oil color will firmly adhere to it, and withstand both heat and damp.

To Protect Roofing from Rust.—Zinc sheets for roofing can easily be protected against rust by the following simple process: Clean the plates by immersing them in water to which 5% of sulphuric acid has been added, then wash with pure water, allow to dry and coat with asphalt varnish. Asphalt varnish is prepared by dissolving 1 to 2 parts asphalt in 10 parts benzine; the solution should be poured evenly over the plates and the latter placed in an upright position to dry.

SIZE

Gold Size.—1.—(Oil Size).—Drying or boiled oil thickened with yellow ocher or calcined red ocher, and carefully reduced to the utmost smoothness by grinding. It is thinned with oil of turpentine. Improves by age. Used for oil gilding.

2.—(Water Size).—Parchment or isinglass size mixed with finely ground yellow ocher. Used in burnished or distemper gilding.

3.—Place boiled oil in a stone pot and place on a gentle fire, and allow the heat to rise almost to the point of ignition, then set fire to it, and let it burn until it is thick, then put on the cover to extinguish the flames. Now strain through silk and thin with turpentine.

4.—The following is highly recommended: Heat slowly 8 oz. best drying oil and just before it comes to a boil add 2 oz. gum animi, boil until of the consistency of tar, then strain through silk. A little finely ground vermilion may be added if desired; thin with turpentine. Dilute with oil of turpentine.

5.—Gold size is prepared from ½ lb. linseed oil with 2 oz. gum animi; the latter is reduced to powder and gradually added to the oil while being heated in a flask, stirring it after every addition until the whole is dissolved; the mixture is boiled until a small quantity, when taken out, is somewhat thicker than tar, and the whole is strained through a coarse cloth. When used, it must be ground with as much vermilion as will render it opaque, and at the same time be diluted with oil

of turpentine, so as to make it work freely with the pencil.

6.—Black Gold Size.—Triturate 1 oz. gold size with enough lampblack to form a dense color. Thin with turpentine.

7.—Japanners' Gold Size.—Lead acetate ¼ lb.; gum animi, 4 lb.; turpentine, 1¾ gal.; drying oil, 1 gal. Boil the gum in the oil for 4 hours, add the other materials and strain.

VARNISHES

What Varnishes Are Made of

Varnish is a solution of resinous matter forming a clear, limpid fluid, capable of hardening without losing its transparency. It is used to give a shining transparent, hard and preservative covering to the finished surface of woodwork, capable of resisting in a greater or less degree the influence of the air and moisture. This coating, when applied to metal or mineral surfaces, takes the name of lacquer, and must be prepared from rosins at once more adhesive and tenacious than those entering into varnish.

The rosins, commonly called gums, appropriate to varnish are of two kinds—the hard and the soft. The hard varieties are copal, amber and the lac rosins. The dry, soft rosins are juniper gum (commonly called sandarac), mastic and dammar. The elastic soft rosins are benzoin, elemi, anime and turpentine. The science of preparing varnish consists in combining these classes of rosins in a suitable solvent, so that each conveys its good qualities and counteracts the bad ones of the others, and in giving the desired color to this solution without affecting the suspension of the rosins, or detracting from the drying and hardening properties of the varnish.

Spirit vs. Oil Varnishes.—In spirit varnish (that made with alcohol) the hard and the elastic gums must be mixed to insure tenderness and solidity, as the alcohol evaporates at once after applying, leaving the varnish wholly dependent on the gums for the tenacious and adhesive properties; and if the soft rosins predominate, the varnish will remain "tacky" for a long time. Spirit varnish, however good and convenient to work with, must always be inferior to oil varnish, as the latter is at the same time more tender and more solid, for the oil, in oxidizing and evaporating, thickens, and forms rosin, which continues its softening and binding presence, whereas in a spirit varnish the alcohol is promptly dissipated, and leaves the gums on the surface of the work in a more or less granular and brittle precipitate, which chips readily and peels off.

Varnish must be tender, and, in a manner, soft. It must yield to the movements of the wood in expanding or contracting with the heat or cold, and must not inclose the wood like a sheet of glass. This is why oil varnish is superior to spirit varnish. To obtain this suppleness the gums must be dissolved in some liquid not highly volatile like spirit, but one which mixes with them in substance permanently to counteract their extreme friability. Such solvents are the oil of lavender, spike, rosemary and turpentine, combined with linseed oil. The vehicle in which the rosins are dissolved must be and remain soft, so as to keep soft the rosins which are, of themselves, naturally hard. Any varnish from which the solvent has been completely dried out must, of necessity, become hard and glassy, and chip off. But, on the other hand, if the varnish remains too soft and "tacky," it will "cake" in time, and destroy the effect desired.

In estimating the quality of a varnish the following points must be considered: 1, quickness in drying; 2, hardness of film or coating; 3, toughness of film; 4, amount of gloss; 5, permanence of gloss of film; 6, durability on exposure to weather.

Ingredients.—Driers are generally added to varnish in the form of litharge, sugar of lead, or white copperas. Sugar of lead not only hardens, but combines with the varnish. A large proportion of driers injures the durability of the varnish, though it causes it to dry more quickly.

1.—For Body and Luster.—Amber, anime, copal, elemi, mastic, sandarac.

2.—For Odor.—Benzoin.

3.—For Tinctorial Effect.—a.—Coloring matters soluble in water and alcohol: Magenta, cardinal, erythrosine, safranine, methylene blue, picric acid, curcumine, metanil yellow, Hofmann violet, malachite green, Bismarck brown, acid magenta, cerise, rose bengal, coccine, peacock blue, naphthol yellow, brilliant yellow, methyl orange, regina purple, brilliant green, vesuvine, rubin, methyl eosine, phloxine, navy blue, phosphine, auramine, chrysoidine, methyl violet, acid mauve, iodine green, crimson, eosine, coralline, benzyl blue, aurantia, chrysophenine, mandarin, acid violet, methyl green.

b.—Coloring matters soluble in water only: Congo, congo corinth, brilliant congo, benzopurpurine, delta purpurine, roseazurine, Hessian purple, fast red, archil red, ponceau, scarlet, azo-rubine,

heliotrope, brilliant blue, wool blue, black blue, benzoazurine, azo-blue, Guernsey blue, Hessian blue, water blue, Bavarian blue, Capri blue, alkali blue, China blue, regina violet, azo-violet, fast brown, acid brown, resorcin brown, guinea green, aniline gray, nigrosine, silver gray, wool black, nacarat, brilliant scarlet, acid yellow, resorcin yellow, quinoline yellow, azo-acid yellow, naphthol yellow, chrysamine, Hessian yellow, curcumine, orange, methly orange, rusin S.

c.—Coloring matters, soluble in alcohol only: Rosaniline base, nigrosine spirit (soluble), Humboldt blue, aurine, malachite green base, new violet, Soudan, brilliant black, auramine base, spirit blue, induline spirit (soluble).

d.—Colors soluble in oil: Rosaniline base, magenta base, oil yellow, butter yellow, violet base, auramine base, oil violet, oil brown, Soudan I, picric acid, oil orange, oil scarlet, Soudan II, oil green, oil crimson.

Practically none of the coal-tar colors are soluble in petroleum spirit, turpentine or benzol. While, therefore, the coal-tar colors are available for coloring water—and spirit—varnishes, but few of them are useful for coloring oil varnishes, and none for coloring varnishes made from turpentine, petroleum spirit, or benzol.

4.—For Color and Body.—Asphaltum.

5.—For Toughness and Elasticity.—Caoutchouc.

Manufacturing Hints—Glass, coarsely powdered, is often added to varnish when mixed in large quantities, for the purpose of cutting the rosins and preventing them from adhering to the bottom and sides of the container. When possible, varnish should always be compounded without the use of heat, as this carbonizes and otherwise changes the constituents, and, besides, danger always ensues from the highly inflammable nature of the material employed. However, when heat is necessary, a water bath should always be used; the varnish should never fill the vessel over a half to three-quarters of its capacity.

The Gums Used in Making Varnish.—Juniper gum, or true sandarac, comes in long, yellowish, dusty tears, and requires a high temperature for its manipulation in oil. The oil must be so hot as to scorch a feather dipped into it, before this gum is added; otherwise, the gum is burnt. Because of this, juniper gum is usually displaced in oil varnish by gum dammar. Both these gums, by their dryness, counteract the elasticity of oil as well as other gums. The usual sandarac of commerce is a brittle, yellow, transparent rosin from Africa, more soluble in turpentine than in alcohol. Its excess renders varnish hard and brittle. Commercial sandarac is also often a mixture of the African rosin with dammar or hard Indian copal, the place of the African rosin being sometimes taken by the true juniper gum. This mixture is the pounce of the shops, and is almost insoluble in alcohol or turpentine. Dammar also largely takes the place of tender copal, gum anime, white amber, white incense and white rosin. The latter three names are also often applied to a mixture of oil and Grecian wax, sometimes used in varnish. When gum dammar is used as the main rosin in a varnish it should be first fused and brought to a boiling point, but not thawed. This eliminates the property that renders dammar varnish soft and "tacky," if not treated as above. Venetian turpentine has a tendency to render varnish "tacky," and must be skilfully counteracted if this effect is to be avoided. Benzoin in varnish exposed to any degree of dampness has a tendency to swell, and must, in such cases, be avoided, Elemi, a fragrant rosin from Egypt, in time grows hard and brittle, and is not so soluble in alcohol as anime, which is highly esteemed for its more tender qualities. Copal is a name given rather indiscriminately to various gums and rosins. The East Indian or African is the tender copal, and is softer and more transparent than the other varieties; when pure, it is freely soluble in oil of turpentine or rosemary. Hard copal comes in its best form from Mexico, and is not readily soluble in oil unless first fused. The brilliant, deep-red color of old varnish is said to be based on dragon's blood, but not the kind that comes in sticks, cones, etc. (which is always adulterated), but the clear, pure tear, deeper in color than a carbuncle, and as crystal fiery as a ruby. This is seldom seen in the market, as is also the tear of gamboge, which, mixed with the tear of dragon's blood, is said to be the basis of the brilliant orange and gold varnish of the ancients.

Amber Varnish

Amber varnish is suited for all purposes, where a very hard and durable oil varnish is required. The paler kind is superior to copal varnish, and is often mixed with the latter to increase its hardness and durability.

1.—Hard.—Melted amber, 4 oz.; hot, boiled oil, 1 qt.

2.—Pale.—Very pale and transparent amber, 4 oz.; clarified linseed oil and oil of turpentine, of each 1 pt.

3.—Amber and Elemi Lacquer.—Amber, 4 parts; elemi, 1 part; Venice turpentine, 1 part; oil of turpentine, 12 parts. This makes a very beautiful and lasting lacquer.

Aniline Varnishes

1.—These are very useful, as the color is intense, even when in a very thin film. Use alcohol to dissolve the shellac or sandarac. Prepare also an alcoholic solution of the aniline colors; add this to the varnish. Warm the object slightly.

2.—Collodion can also be used to carry the aniline colors, and gives a very thin coating.

Asphalt Varnish

Boil coal tar until it shows a disposition to harden on cooling; this can be ascertained by rubbing a little on a piece of metal. Then add about 20% of lump asphalt, stirring it with the boiling coal tar until all the lumps are melted, when it can be allowed to cool and kept for use. This makes a very bright varnish for sheet metals, and is cheap and durable.

Balloon Varnish

Carl E. Myers, the aeronaut, gives the following exclusive information, which is copyright, 1908, by Munn & Co.:

1.—The matter of balloon varnish seems to be giving a lot of trouble. It always has, more or less, as commercial varnish manufacturers do not make balloon varnishes, and none of the ordinary varnishes serve well for balloons. What is wanted is an elastic, non-adhesive and enduring varnish, that will not heat or spontaneously decompose. Pure boiled linseed oil comes the nearest to these requirements. The difficulty is in getting it pure, to begin with, and keeping it unmixed with oxides or dryers when boiled. Any such admixtures lay the seeds of destruction, for oxidizing, if once started, is kept up continuously till the mass is rusted or rotted finally, and the fabric made brittle or sticky, and soon useless. Balloon varnish is not a matter of formula or recipe, but a process or system of preparation, and thus requires experience, judgment, and, to some extent, courage, as it is more or less dangerous to produce good linseed-oil varnish cooked at a high temperature. I have known one large varnish factory to be entirely destroyed in attempting to make balloon varnish, and I have seen over a hundred conflagrations of more or less magnitude result from boiling oil to make balloon varnish. I only make balloon varnish once a year, in considerable quantities, requiring weeks with special apparatus, on a manufacturing scale, and I aim to keep a year's supply on hand, and use the oldest and best. My varnishing is done by patent machinery, permitting the use of pure linseed-oil varnish too thick to spread by hand brushes. One thousand yards of surface require about an hour's work, all superficial varnish being removed by the machines, after which the fabric is dried spontaneously in the hot sun, without oxidizing driers. This process is repeated several times till 7 to 9 films are superimposed, with increased thickness, appreciable by a micrometer caliper after the first coat is applied. The microscopic pores in each film do not coincide, or are plugged up, resulting in a practically hydrogen-proof fabric, of light weight and thickness, which can be folded or rolled repeatedly without fracture of the films at ordinary temperature, and which never decomposes or sticks or becomes rotten when packed. I have tried very many preparations, and found them mostly unsuitable for continued usefulness. The best of these include good boiled linseed oil as a basis, thinned with best spirits of turpentine or stove gasolene, for use with hard brushes. Driers to be used are chiefly litharge or "japan" and chrome yellow. "Birdlime" and rubber are sometimes mixed in small quantities with linseed-oil varnish, and are of doubtful value. Raw or half-boiled linseed oil will never make other than a sticky coat, necessitating frequent dusting with talc chalk, or other similar preparations, and will inevitably ruin any balloon coated with it. While almost any varnish, in repeated layers, will serve to hold gas temporarily, or for immediate use, on a balloon, such vessels are short-lived, heavier than desirable, and not satisfactory for airships or vessels required to hold hydrogen for a long time.

Black Varnish

1.—Shellac, 8 parts; rosin, 5 parts; lampblack, 1 part; alcohol, 94%, 32 parts If a dead black be required, use the same proportion of ingredients, with oil of turpentine as the solvent.

2.—In an iron pot, over a slow fire, boil 45 lb. of foreign asphaltum for at least 6 hours, and during the same time boil in another iron pot 6 gal. of oil which has been previously boiled; during the boiling of the 6 gal. introduce 6 lb. of litharge gradually, and boil until it feels

stringy between the fingers; then ladle it into the pot containing the boiling asphaltum. Let both boil until, upon trial, it will roll into hard pills; then cool, and mix with 25 gal. of turpentine, or until it is of proper consistency.

3.—Black varnish suitable for covering places where a japanned surface has been injured or scratched: Fine lampblack or ivory black, thoroughly mixed with copal varnish. The black must be in fine powder, and it would mix the more readily if made into a pasty mass with turpentine.

4.—Black varnish can be made by putting 48 lb. of foreign asphaltum into an iron pot and boiling for 4 hours; during the first 2 hours introduce 7 lb. of red lead, 7 lb. of litharge, 3 lb. of dried copperas and 10 gal. of boiled oil; add one 8-lb. run of dark gum with 2 gal. of hot oil. After pouring the oil and gum continue the boiling 2 hours, or until it will roll into hard pills like japan. When cool, thin it off with 30 gal. of turpentine, or until it is of proper consistency. This varnish is specially adapted for iron-work.

Body Varnish

1.—Finest African copal, 8 lb.; fuse carefully, add clarified oil, 2 gal.; boil gently for 4½ hours, or till quite stringy, cool a little, and thin with oil of turpentine, 3½ gal. Dries slowly.

2.—Pale gum copal, 8 lb.; clarified oil, 2 gal.; dried sugar of lead ½ lb.; boil as before, then add oil of turpentine, 3½ gal., and mix it, while still hot, with the following varnish: Pale gum anime, 8 lb.; linseed oil, 2 gal.; dried white copperas, ¼ lb.; boil as before, and thin with oil of turpentine, 3½ gal.; the mixed varnishes are to be immediately strained into the cans or cistern.

Brass

1.—Boil in alcohol, turmeric, 24 parts; saffron, 5 parts. This is filtered and heated in a water bath, in this tincture: Gamboge, 24 parts; elemi, 90 parts; dragon's blood, 30 parts; alcohol, 500 parts.

2.—Black Letters for Brass Signs.—A formula for a black japan adapted to the purpose is as follows: Asphaltum, 8 oz.; dark gum anime, ½ oz.; linseed oil, 18 oz.; dark gum amber, 1½ oz.; turpentine spirit, 2½ pt. Fuse together the asphaltum and gum anime, and add 15 oz. of the linseed oil. Boil the amber, previously fused with 3 oz. of the linseed oil, and add to the mixture. Continue the boiling until a little of the mass, when cooled, is plastic; then withdraw the heat and add the turpentine. The enamel process is altogether different, and consists in fusing on the brass a kind of glass, which, when cool, adheres to the metal. The preparation of the enamel involves special skill, and its application is also a matter not likely to be within the reach of the amateur.

Caseine Varnish

According to Ammundsen, this is prepared as follows: Caseine, 100 parts; 10% solution of soap, 10 to 25 parts; slaked lime, 20 to 25 parts; oil of turpentine, 25 to 40 parts; water, sufficient. Mix the caseine with the soap solution; add the lime, and rub up to a homogeneous mixture. Now add the turpentine gradually, and with constant strring, Add water to attain the desired consistency. The addition of a little ammonia water tends to aid this preparation in keeping. This is a very cheap and excellent varnish.

Celluloid Varnishes

1.—Celluloid, 5 parts; sulphuric ether, 16 parts; acetone 16 parts; amyl acetate, 16 parts. Mix and dissolve.

2.—Celluloid, 10 parts; camphor, 4 parts; sulphuric ether, 30 parts; acetone, 30 parts; amyl acetate, 30 gr. Mix and dissolve.

3.—Celluloid, 5 parts; camphor, 5 parts; alcohol, 50 parts. Mix and dissolve.

4.—Celluloid, 5 parts; amyl acetate, 5 parts. Mix.

5.—Celluloid, 5 parts; acetone, 25 parts; amyl acetate, 25 parts. Mix and dissolve. The ingredients of the above five formulas are inflammable.

Chimneys and Stove Pipes, Varnish for

Asphaltum, 2 lb.; boiled linseed oil, 1 pt.; oil of turpentine, 2 qt. Fuse the asphaltum in an iron pot, boil the linseed oil, and add while hot. Stir well, and remove from the fire. When partially cooled add the oil of turpentine.

Coal Buckets, Black Varnish for

Asphaltum, 1½ lb.; lampblack, ⅜ lb.; rosin, ¾ lb.; spirits of turpentine, 1½ qt. Dissolve the rosin and asphaltum in the turpentine; form a paste with the lampblack and linseed oil, q. s.; mix with the other. Apply with a brush.

Collodion

1.—Add 1 oz. of castor oil to 1 qt. of collodion. This is a very useful varnish for varnishing maps, etc.

2.—Hale's formula is as follows: Amyl acetate, 4 gal.; benzine (coal naphtha), 4 gal.; acetone, 2 gal.; pyroxyline, 2½ lb. The different ingredients are mixed and the pyroxyline dissolved therein. The metal article, having its surface polished and made free from water and grease by any ordinary or suitable means, is, or may be, dipped into a solution made according to either of the formulæ, and on removal therefrom suspended in a chamber out of the draught till the adhering coat or film dries or hardens, which takes place in about 15 or 20 minutes. The drying may be hastened by artificial heat, and while the use of the heat at any stage of the process is not inconsistent with the invention, yet it is preferred to operate in the cold—that is, at ordinary temperatures. In damp weather the coating should be dried at a temperature of, say, 100 to 105° F. The varnish or solution may also be applied by brushing. The coated articles, when the coatings are dry, have their metal surfaces provided with a substantial, even, hard, thin, smooth, impervious and transparent film of pyroxyline of sufficient tenacity, adhesion and durability practically to resist the handling and exposure to which lacquered articles in general are subjected.

Copal Varnish

1.—Turpentine.—Oil of turpentine, 1 pt.; set the bottle in a water bath, and add, in small portions at a time, 3 oz. of powdered copal that has been previously melted by a gentle heat, and dropped into water; in a few days decant the clear. Dries slowly, but is very pale and durable. Used for pictures, etc.

2.—Oil.—Pale and hard copal, 2 lb.; fuse, add hot drying oil, 1 pt.; boil as before directed, and thin with oil of turpentine, 3 pt., 12 oz.; or q. s.

3.—Clearest and palest African copal, 8 lb.; fuse, add hot and pale drying oil, 2 gal.; boil till it strings strongly, cool a little, and thin with hot rectified oil of turpentine, 3 gal., and immediately strain into the store can. Very fine. Both the above are used for pictures.

4.—Spirit.—Coarsely powdered copal and glass, of each 4 oz.; 90% alcohol, 1 pt.; camphor, ½ oz.; heat in a water bath, so that the bubbles may be counted as they rise, observing frequently to stir the mixture; when cold decant the clear. Used for pictures.

5.—Copal Varnish with Ammonia.—Grind copal to a coarse powder, and pour ammonia over it until the whole mass is swelled up. Heat this to about 100° F., then add alcohol until the mixture is of the desired consistency.

6.—Camphorated Copal Varnish.—Take powdered copal, 4 oz.; essential oil of lavender, 12 oz.; camphor, ¼ oz.; and as much spirit of turpentine as will produce the required consistency. Heat the oil and the camphor in a small matrass, stirring them, and putting in the copal and turpentine in the same manner as for gold-colored copal varnish.

7.—Elastic.—Gum camphor, 60 parts; copal, 250 parts; ether, 700 parts. Keep in a bottle with a ground-glass stopper; use the upper portion, which will become clear after a few days, or possibly weeks. This sediment has a new portion of the mixed substance added, the ether being in excess, only ½ as much camphor and copal being added.

Dammar Turpentine Varnishes

1.—Gum dammar is a soft copal, and possesses the property of solubility in nearly every solvent, including turpentine and methylated spirit. It varies in color from yellow to nearly water-white, and should be carefully selected according to the grade of varnish it is desired to make. Dammar varnishes are chiefly used as paper varnishes (the best quality being termed crystal paper varnishes), and as varnishes for enamels.

2.—Turpentine, 160 fl.oz.; gum dammar, 80 oz.; sandarac rosin, 40 oz.; mastic rosin, 8 oz.

Dead Surface Varnish

Varnishes that leave a dead surface on drying, capable of substitution for ground glass, as for glass stereographs, and of use in retouching negatives, may be made by mixing solutions of rosin with liquids in which they are insoluble. A solution of sandarac rosin in ether, when mixed with ¼ as much benzole, affords an excellent imitation of ground glass; one of dammar rosin in benzole, when mixed with ether, also gives a good dead surface; water instead of ether renders it, at the same time, semi-opaque. A mixture of benzole with common negative varnish frequently, but not always, gives a beautiful dead surface. In all cases a great deal depends on the purity of the ingredients. It is recommended to dissolve from 3 to 5 parts of sandarac in 48 parts of ether, and to add 24 parts of benzole; or as much as may be necessary to produce the desired result. The following, by Hughes, is said to give perfectly colorless varnish of this kind: Ether, 560 gr.; benzole, 240 gr.; sandarac, 40 gr.; Canada balsam, 10 gr. The rosins are

first to be dissolved in the ether, and the benzole added to the solution.

Electrical Varnish

A varnish formed by dissolving orange shellac in 95% alcohol is indispensable for all kinds of electrical work, and for finishing wood and metal work. It may be readily colored by the addition of pigments. For brown, the red and black may be mixed; for purple, the red and blue; for yellow, finely powdered yellow ocher or chrome yellow may be added; for a dead black varnish, alcohol, with a small percentage of shellac varnish added, mixed with calcined lampblack, answers an excellent purpose.

Ether Varnish

Take 1 oz. of amber-colored copal, finely powdered, and place it in a flask containing 4 oz. of ether; cork the flask with a glass stopper, and shake it for half an hour. Let it rest until the liquor becomes perfectly clear.

Fatty Varnish, for Painters

Sandarac, 120 grams; mastic 30 grams; Venetian turpentine, 6 grams; boiled linseed oil, or poppy oil, 750 grams; spirits of turpentine, 90 grams.

Flexible Varnish

1.—India-rubber, cut small, 1½ oz.; chloroform, ether, or carbon bisulphide, 20 fl.oz.; digest without heat until the solution is complete.

2.—Same, only substituting gutta percha for india-rubber.

3.—Dissolve 1 oz. of india-rubber in 1 pt. of benzole by digesting with gentle heat. This varnish dries badly.

Guns

Barrels.—1.—Shellac, 1½ oz.; dragon's blood, 3 dr.; rectified spirit, 1 qt. Apply after the barrels are browned.

2.—Stocks.—Shellac, 5 oz.; sandarac, ½ oz.; Venice turpentine, 1 dr.; alcohol, 2 qt.

Gutta Percha Varnish

Clean ¼ lb. of gutta percha in warm water from adhering impurities, dry well, dissolve in 1 lb. of rectified rosin oil, and add 2 lb. of linseed-oil varnish, boiling hot.

India Rubber Varnish

1.—India-rubber, finely divided, 2 oz., placed in a phial, and digested in a sand bath, with ¼ lb. of camphene and ¼ oz. of naphtha. When dissolved, add 1 oz. of copal varnish, which renders it more durable.

2.—Digest in a wide-mouthed glass bottle 2 oz. of india rubber in shavings, with 1 lb. of oil of turpentine, during 2 days, without shaking; then stir up with a wooden spatula. Add another pound of oil of turpentine, and digest, with frequent agitation, until all is dissolved. Mix 1½ lb. of this solution with 2 lb. of white copal-oil varnish, and 1½ lb. of boiled linseed oil; shake, and digest in a sand bath until they have united into a good varnish.

Inflexible

Shellac, 4 oz.; wood naphtha, 1 pt.; lampblack, q. s. to color; dissolve.

Insulating Varnishes

For Earth Cables and Exposed Strong Current Wires.—1.—Melt 2 parts of asphalt together with 0.4 part of sulphur; add 5 parts of linseed-oil varnish, linseed oil or cotton-seend oil, keep at 160° C. for 6 hours; next pour in oil of turpentine as required.

2.—Mix 3 parts of elaterite with 2 parts of linseed-oil varnish at 200° C. for 5 to 6 hours; next, melt 3 parts of asphalt, pour both substances together, and again maintain the temperature of 200° C. for 3 or 4 hours, and then add 1 part of linseed-oil varnish and oil of turpentine, as required.

Dynamos and Conduits with Low Tension.—a.—Shellac, 4 parts; sandarac, 2 parts; linoleic acid, 2 parts; alcohol, 15 parts.

b.—Shellac, 4 parts; sandarac, 4 parts; elemi, 1 part; alcohol, 20 parts.

Shellac Varnish (Used by Large Electrical Works).—a.—Shellac, 100 lb.; methylated spirit, 40 gal. Contains no auramine or oxalic, but may contain acid brown or Bismarck brown.

b.—Extra Stout.—Shellac, 84 lb.; methylated spirit, 12 gal. Auramine and oxalic acid. Makes 19 gal.

Iron and Steel

1.—Dissolve in alcohol: Mastic, 10 parts; camphor, 5 parts; sandarac, 15 parts; elemi, 5 parts. Apply cold.

2.—Iron Work.—a.—Dissolve in about 2 lb. tar oil, ½ lb. asphaltum, and a like quantity of pounded rosin, mix hot in an iron kettle, care being taken to prevent any contact with the flame. When cold the varnish is ready for use. This varnish is for outdoor wood and iron work.

b.—Black Varnish.—Boil sulphur in turpentine, apply with a brush and after heating, the iron becomes of an intense and brilliant black.

c.—Sheet Iron.—Melted colophony, 60 gr.; amber, 90 gr. After fusion and cooling, add: Spirits of turpentine, 45 gr.; painters' varnish, 45 gr. If the varnish is too thick, dilute it with essence.

3.—Preservative Varnish for Iron Work.—a.—Common rosin, 56 lb.; gutta percha, 2 lb.; dried sulphate of zinc, 2 lb.; mineral naphtha, 8 gal. Sweat the rosin and gutta percha together, then sprinkle in the sulphate of zinc, cool to 130° F., and add the naphtha.

b.—(Also used as a first coating for ships' bottoms, previous to the application of anti-fouling compositions.)—Common rosin, 112 lb.; gutta percha, 8 lb.; stearate of zinc, 8 lb.; mineral naphtha*, 24 gal. (*) This may be coal tar naphtha or benzine.

c.—Stearate of Zinc (used in above).—White curd soap, 28 lb.; sulphate of zinc, 8 lb. Process.—Dissolve the sulphate of zinc and soap separately in boiling water. Mix together while boiling, dry and fuse stearate for use.

4.—Smiths, Locksmiths and Iron Founders.—a.—Heat 200 parts by weight of pine oil and dissolve in it 25 parts of Syrian asphalt and 25 parts of rosin, previously crushed a little. When cool, pour the varnish into a bottle and keep. When heating the pine oil, be careful that the vapors do not come into contact with the fire or the oil will ignite.

b.—Brown Varnish for Locksmiths' Goods.—Such a varnish for bright goods to be dried in the stove is prepared as follows: Heat 10 parts of Syrian or Gisonite asphalt, 30 parts of matured linseed oil, 2 parts of red lead, and 2 parts of litharge until the mixture draws threads, let cool, and stir 30 parts of oil turpentine into it.

Japan Varnish, Black

Naples asphaltum, 50 lb.; dark gum arabic, 8 lb. Fuse, add 12 gal. linseed oil; boil, then add of dark gum amber, 10 lb., previously fused and boiled in 2 gal. linseed oil; next add q. s. of driers and thin with oil of turpentine.

Lac Varnish

1.—Seed lac, 8 oz.; alcohol, 1 qt.; digest in a close vessel in a warm situation for 3 or 4 days, then decant and strain. Highly recommended.

2.—Substitute lac bleached by chlorine for seed lac. Both are very tough, hard and durable, the last almost colorless. Used for pictures, metal, wood or leather.

3.—Lac Water Varnish.—Pale shellac, 5 oz.; borax, 1 oz.; water, 1 pt. Digest at nearly the boiling point till dissolved, then strain. An excellent vehicle for water colors, inks, etc., and a varnish for prints is made thus of bleached lac. When dry, it is transparent and waterproof.

Leather Paints and Varnishes

1.—Shellac, 1 part; turpentine, 5 parts; prepared spirit, 15 parts. To prepare the spirit add to every 15 l. of alcohol (wood) 500 gr. extract of logwood and 25 gr. of potassium dichromate and dissolve; then add the shellac and turpentine.

2.—Ruby shellac, 30 parts; Venice turpentine, 1 part; sandarac, 1 part; castor oil, 1 part; alcohol, 150 parts; levelin black, 5 parts.

3.—Rosin, 3 parts; turpentine, 3 parts; oil turpentine, 3 parts; sandarac, 6 parts; shellac, 12 parts; lampblack, 1 to 5 parts; alcohol, 90%, 90 parts.

4.—Venice turpentine, 3 oz.; alcohol, 8 oz.; nigrosine, 30 gr.; aniline blue, 8 gr. Dissolve the aniline colors in a little alcohol before adding to the other ingredients.

5.—a.—Durable leather varnish is composed of boiled linseed oil, in which a drier, such as litharge, has been boiled. It is colored with lampblack. This varnish is used for making enameled leather.

b.—Shellac, 12 parts; white turpentine, 5 parts; gum sandarac, 2 parts; lampblack, 1 part; spirits of turpentine, 4 parts; alcohol, 96 parts.

c.—Dull Black.—Alcohol, 95%, 500 parts; shellac, 125 parts; wax, 15 parts; turpentine, 10 parts; spirit-soluble nigrosine, 10 to 15 parts.

d.—Glossy Black, Volatile.—1.—Alcohol, 95%, 500 parts; shellac, 70 parts; turpentine, 20 parts; spirit-soluble nigrosine, 10 parts.

2.—Alcohol, 95%, 500 parts; shellac, 90 parts; sandarac, 15 parts; turpentine, 10 parts; castor oil, 6 parts; spirit-soluble nigrosine, 12 to 15 parts.

3.—Alcohol, 95%, 500 parts; shellac, 70 parts; colophony, 30 parts; rosin oil, 10 parts; turpentine, 10 parts; spirit-soluble nigrosine, 10 to 15 parts.

4.—Alcohol, 95%, 500 parts; shellac, 60 parts; sandarac, 25 parts; colophony, 15 parts; turpentine, 25 parts; turpentine oil, 15 parts; spirit-soluble nigrosine, 12 to 15 parts.

Linseed Oil Varnish

Boil linseed oil, 60 parts, with litharge, 2 parts; white vitriol, 1 part; each finely powdered until all water is evaporated. Then set by. Or, rub up borate of manganese, 4 parts, with some of the oil, then

add linseed oil, 3,000 parts, and heat to boiling.

Machinery

1.—Asphaltum Varnish.—First paint the articles in a japan color such as the following: Asphaltum, 3 oz.; boiled oil, 4 qt.; burned umber, 8 oz. Mix by heat, and when cooling, thin with turpentine. Then coat them with a suitable transparent or light varnish.

2.—Agricultural Machines.—Obtainable in a variety of colors such as green, red, blue, etc., they must possess brilliant luster and adhere to the iron almost as firmly as enamel. They may be produced, of excellent quality, according to the following recipe: In 120 parts of 95% alcohol dissolve 80 parts of soft manilla copal, 40 parts rosin, and when the solution is complete add 30 parts of castor oil. The varnish is rubbed down, in the prporton of 4 to 7, with any desired bright color. (See also IRON; METALS.)

Metals

1.—To make alcoholic lacquers or varnishes adhere more completely to polished metal surfaces, 1 part boracic acid should be added to 200 parts of varnish. This composition will adhere so firmly and become so completely glazed as to be removed only with difficulty. Be careful not to add too much of the boracic acid, as it injures the gloss in that case.

2.—Copal, 1 part; alcohol, 2 parts.

3.—Copal, 1 part; oil rosemary, 2 or 3 parts; alcohol. Apply hot.

Optical Goods and Ornamental Iron Work, Dead Black for

Dissolve seed lac in 95% alcohol q. s. Mixed refined lampblack with alcohol and add enough seed lac varnish to make the lampblack adhere, but not enough to give it a gloss. Strain through cheese cloth. Apply with a soft varnish brush.

Patterns, Varnish for

1.—Alcohol, 1 gal.; shellac, 1 lb. Lamp or ivory black, sufficient to color it.

2.—Shellac, 30 lb.; manilla copal, 10 lb.;. and Zanzibar copal, 10 lb., are placed in a vessel, which is heated externally by steam, and stored during 4 to 6 hours, after which 150 parts of the finest potato spirit are added, and the whole heated during 4 hours to 87° C. This liquid is dyed by the addition of orange color, and can then be used for painting the patterns.

Rosin Benzine Varnish

Rosin, 250 lb.; oxide of manganese, 7 lb.; benzine, 35 gal.

Rosin Turpentine Varnish

Dark rosin, 100 lb.; turps, 8 gal. Put 100 lb. dark rosin in pot, add turps with it. Put on slow fire until all the rosin has melted; take off fire. If too stout, add more turps.

Rubber, Shellac Varnish for

1.—Powder shellac and soak in well-stoppered bottle with 10 times its weight of strong ammonia. Allow it to stand for a number of days, when the shellac disappears. Sometimes several weeks are required to effect complete solution. If for use on overshoes, add a little lampblack.

2.—Rubbers.—Dissolve 1 oz. finely powdered shellac in 10 oz. of strong ammonia. This must be kept in a bottle with a ground glass stopper. After several days the shellac will become dissolved. Apply with a rag.

Sealing Wax Varnish

Dissolve sealing wax of any color in strong alcohol. Apt to be rather brittle.

Shellac Varnish

1.—(a) Shellac, 60 grams; (b) alcohol, 60 grams; (c) castor oil, 25 grams; (d) alcoholic solution of aniline dye, a few drops. (a) and (b) are dissolved, and heated until quite thick, then a little of (d) is added, and for every 60 grams of the mixture add 25 grams of castor oil, and heat for a short time.

2.—Harris'.—Put 1 oz. shellac into a wide-mouthed 8 oz. phial, containing 5 oz. of rectified naphtha or wood spirit. Cork and stand in a warm place until the gum is dissolved. Shake frequently and filter, adding more naphtha to assist the filtering, and changing the filter from time to time.

3.—Imitation.—The following article under this name is used by furniture dealers: Gum sandarac, 1½ lb.; pale rosin, 1½ lb.; benzine, 2 gal. Dissolve by gentle heat. The varnish is quick-drying.

4.—White.—Dissolve 1 part of pearlash in about 8 parts of water; add 1 part of shellac, and heat the whole to the boiling point. When the lac is dissolved, cool the solution, and saturate it with chlorine until the lac has all settled. When it is dissolved in alcohol it forms a varnish which is transparent as any copal varnish.

Silver

1.—Gum elemi, 30 parts; white amber, 45 parts; charcoal, 30 parts; spirits of turpentine, 375 parts. It must be used

in a heated state, the metal to which it is to be applied being also heated.

2.—Oxidized.—Alcohol, 16 parts; red arsenic, 3 parts; essence lavender, 1 part. (Parts by weight.)

Spirit Varnish

Brown.—The best do not contain rosin. Sandarac, 3 lb.; pale shellac, 2 lb.; spirit, 2 gal.; turpentine, 2 pt. Dissolve the sandarac and shellac in the spirit, and add the turpentine.

Hard.—1.—Gum lac, 20 parts; juniper gum, 8 parts; elemi, 4 parts; alcohol, 100 parts.

2.—Brown.—a.—Sandarac, 4 oz.; pale seed lac, 2 oz.; elemi (true), 1 oz.; alcohol, 1 qt. Digest with agitation till dissolved, then add Venice turpentine, 2 oz.

b.—Gum sandarac, 3 lb.; shellac, 2 lb.; alcohol (65 over proof), 2 gal. Dissolve, add turpentine varnish, 1 qt.; agitate well and strain. Very fine.

c.—Seed lac, 1½ lb.; yellow rosin, 1½ lb.; rectified alcohol, 2 gal.

d.—Methylated spirit, 160 fl.oz.; shellac, 8 oz.; sandarac rosin, 16 oz.; elemi rosin, 4 oz.; Venice turpentine, 4 oz.

e.—Brown (for common purposes).—Methylated spirit, 160 fl.oz.; shellac, 12 oz.; rosin, 12 oz.

3.—White.—a.—Methylated spirit, 160 fl.oz.; sandarac rosin, 40 oz.; gum thus, 16 oz.

b.—Methylated spirit (65 above proof), 160 fl.oz.; sandarac rosin, 40 oz.; camphor, ½ oz.; coarsely powdered glass, 16 oz. After straining, add 20 fl.oz. of pale turpentine varnish.

c.—Methylated spirit, 160 fl.oz.; sandarac rosin, 24 oz.; mastic rosin, 8 oz.; elemi rosin, 4 oz. All the above hard varnishes can be polished when dry and hard. They should be laid on with a brush used always in one direction, so as not to generate froth, for if they do, they dry dull and lusterless; 24 hours is usually sufficient time to allow them before proceeding to polish.

Tar Varnish for Wood or Iron

Coal tar, 1½ gal.; spirits of turpentine, ¾ pt.; oil of vitriol, 3 oz. Mix the tar and vitriol together with a stick, and apply with a brush as it becomes thick.

Terra Cotta

Mastic, 1 part; shellac, 10 parts; Venice turpentine, 3 parts; strong alcohol, 20 parts.

Tinner's Varnish

1.—Mix lampblack with shellac.

2.—Mix Frankfort black with shellac.

3.—Mix Frankfort black with a mixture of asphaltum and oil of turpentine, then add a little linseed oil and minium. The exact proportions of tinners' varnishes are immaterial.

Tools, Lacquer for

1.—Yellow wax, 4 parts; Berlin blue, 2 parts; lampblack, 1 part; turpentine oil, 16 parts; neatsfoot oil, q. s. Rub up the blue and lampblack with sufficient of the oil to make a stiff, doughy mass, and add it to the solution of the wax in the oil.

2.—Dissolve 250 grams of bleached shellac in 250 grams of alcohol, and dip the tools into it, when they may be hung up to dry.

3.—Tallow, 4 oz.; rosin, 2 oz.; melt, and strain while hot. With a brush apply a coat to the tools and it will prevent their rusting.

Turner's Lacquer

Gum elemi, 4 parts; shellac (bleached), 20 parts; Venice turpentine, 4 parts; strong alcohol, 60 parts.

Turpentine Varnish

To 1 pt. of spirits or turpentine add 10 oz. of clear rosin, pounded; put it in a tin can on a stove and let it boil for half an hour. When the rosin is all dissolved, let it cool and it is ready for use.

Veneer Liquid

Gum anime, 8 lb.; clarified linseed oil, 3 gal.; litharge, ¼ lb.; lead acetate, ¼ lb.; iron sulphate, ¼ lb.; oil of turpentine, 5½ gal. Boil all together until the mixture strings, then mix well and strain. The aniline colors used to give such varnishes the desired shades are those known as "fat aniline colors" or "Soudan dyes." A small quantity of the desired color is mixed with a little oil of turpentine and then stirred into the varnish. These colors are not known as "oak stain" or "rosewood," but as reds, browns, etc. The proper proportions and blending would have to be learned from practice.

Water Varnishes

1.—Crystal Water Varnish.—1 lb. of good white gum arabic and 1 lb. of glucose are dissolved in 3 pints of water. This dries hard with a gloss.

2.—Glazing Varnish.—Mix 1 pint of white of egg with 1 pint of water. A little carbolic acid or salicylic acid or, better, thymol should be added to preserve this varnish. This varnish or glaze dries

with a fair amount of luster. If, after being applied, it be placed in a hot room to dry, the coat will be made more waterproof. Dried albumen may be used instead of the white of egg by dissolving 1 oz. in 1 pt. of water; only the color of the glaze is not so good.

3.—Glue Varnish.—Made by dissolving 1 lb. of good pale glue in 2 gal. water. The color of this varnish depends very much on the quality of the glue used; if the best gelatine, then a white varnish will be made; if a brown glue, then a brown varnish. This varnish is not very good because of the sticky coat it gives, which is not waterproof; by adding just before using, a small quantity of bichromate of potassium (1 oz. in 2 gal.), the coat becomes nearly waterproof. It is important that the bichromate be added only just before use, as it would act on the varnish and cause it to set into a gelatinous unworkable mass. This varnish forms the basis of some leather varnishes. A little thymol or borax may be added as a preservative.

4.—Lac Water Varnish.—Shellac, 6 oz.; borax, 1½ oz.; and water, 1 pt. Boil together until the lac is dissolved. If bleached lac is used a white varnish will be made; if the orange shellac, the varnish will have a pale brown color. This varnish makes a fair vehicle for water colors; it is good paper varnish, and dries with a fair luster and with a hard coat which is waterproof. By adding any of the soluble coal-tar colors colored varnish can be made.

White Varnish

1.—Tender copal, 7½ oz.; camphor, 1 oz.; alcohol of 95%; 1 qt. Dissolve, then add mastic, 2 oz.; Venice turpentine, 1 oz. Dissolve and strain. Very white, drying, and capable of being polished when hard. Used for toys.

2.—Sandarac, 8 oz.; mastic, 2 oz.; Canada balsam, 4 oz.; alcohol, 1 qt. Ninety per cent. alcohol, 1 qt.; gum sandarac, 10 oz.; gum mastic, 2 oz.; gum anime, ½ oz. Dissolve in a clean can, with gentle heat. Agitate well when the gums are dissolved; strain through a lawn sieve.

3.—Susceptible to polish for jambs, lintels, etc. Mastic, in drops, 12 to 13 dkgrm.; sandarac, 48 to 49 dkgrm.; elemi, 6 dkgrm.; Venetian turpentine, 2 l.; alcohol, 2.

4.—Soft White Varnish.—Methylated spirit, 160 fl.oz.; sandarac rosin, 24 oz.; gum elemi, 16 oz.; anime rosin, 4 oz.; camphor, 2 oz.

WHITEWASH.

1.—Lime, clean and well burnt, 6 qt.; Spanish whiting, or powdered burnt alum, 4 oz.; white sugar, 16 oz.; rice flour, 3 pt.; glue, of good quality, 16 oz.; water, boiling, 5 gal. Slake lime in vessel about 10 gal. capacity, with hot water, keeping vessel covered to retain the steam, and pass through a sieve to clear of coarse particles. Make up the rice flour to a thick paste and boil well, and dissolve the glue in water over a water bath; then mix the liquids with the remainder of the water, and add the whiting or alum and the sugar. The mixture should be applied warm on outdoor surfaces, and cold indoors.

2.—A good durable whitewash is made as follows: Take ½ bushel of freshly burnt lime, slake it with boiling water; cover it during the process, to keep in the steam. Strain the liquid through a fine sieve, and add to it 7 lb. of salt previously well dissolved in warm water; 3 lb. of ground rice boiled to a thin paste and stirred in boiling hot; ½ lb. of powdered Spanish whiting; 1 lb. of clean glue, which has been previously dissolved by soaking it well, and then hanging it over a slow fire in a small kettle within a large one filled with water. Add 5 gal. of hot water to the mixture, stir it well, and let it stand a few days covered from dirt. It must be put on quite hot. For this purpose it can be kept in a kettle on a portable furnace. About 1 pt. of this mixture will cover a square yard.

3.—Paris white, 560 parts; zinc white, 160 parts; plaster of paris, 160 parts; white dextrine, 39 parts; gum acacia, 16 parts; borax 9½ parts; alum, 9½ parts. Put up in pound packets, and direct a pint of boiling water to be added to the contents of a packet, the mixture afterwards to be thinned with cold water to a suitable consistency. Tinting is managed by adding a proportion of various ochers until the right shade is obtained.

4.—To Color and Prevent Whitewash from Rubbing Off.—Give the desired color by adding small quantities of lampblack, brown sienna, ocher, or other coloring material. Add alum to lime whitewash to prevent rubbing off.

5.—Damp Walls.—For brickwork exposed to damp, take half a peck of well burned quicklime, fresh from the kiln. slake with hot water sufficient to reduce it to a paste, and pass it through a fine sieve; add a gallon of clean white salt which has been dissolved. in a small quantity of boiling water. and a thin, smooth paste, also hot, made from 1 lb. of fine rice

flour; also ¼ of a lb. of the best white glue, made in the water bath. Mix together, stir well, add ¼ of a lb. of best Spanish whiting in 5 qt. of boiling water; stir, cover to retain heat and exclude dust, and let it stand a week. Heat to boiling, stir, and apply hot. The above proportions will cover forty square yards.

6.—Fences, etc.—a.—White lime, ½ bushel; hydraulic cement, 3 pecks; umber and ocher, each 10 lb.; Venetian red, 1 lb.; lampblack, ¼ lb.; slake the lime, shake up the lampblack with a little vinegar, mix well together, add the cement, and fill the barrel with water. Let it stand several hours; stir frequently. A larger proportion of ocher gives a darker color. Use only 1 coat. This is said to look well after five years' use.

b.—Slake the lime in boiling water. To ½ gal. ordinary whitewash add ½ pt. molasses and ½ pt. table salt. Stir frequently while applying.

c.—Quicklime, ¼ bu.; slake, add ½ lb. common salt; ¼ lb. sulphate of zinc (white vitriol); 2 qt. sweet milk. Dissolve the salt and white vitriol before adding. Mix with sufficient water to give the proper consistency. Apply as soon as possible.

7.—Government Whitewash.—The following coating for rough brick walls is used by the U. S. government for painting lighthouses, and it effectually prevents moisture from striking through: Take of fresh Rosendale cement, 3 parts, and of clean, fine sand, 1 part; mix with fresh water thoroughly. This gives a gray or granite color, dark or light, according to the color of the cement. If brick color is desired, add enough Venetian red to the mixture to produce the color. If a very light color is desired, lime may be used with the cement and sand. Care must be taken to have all the ingredients well mixed together. In applying the wash, the wall must be wet with clean fresh water; then follow immediately with the cement wash. This prevents the bricks from absorbing the water from the wash too rapidly, and gives time for the cement to set. The wash must be well stirred during the application. The mixture is to be made as thick as can be applied conveniently with a whitewash brush. It is admirably suited for brickwork, fences, etc., but it cannot be used to advantage over paint whitewash.

CHAPTER X.

RUBBER, GUTTA PERCHA AND CELLULOID

CELLULOID

Coloring Finished Celluloid Articles

Though celluloid is obtainable in a variety of colors, it is sometimes necessary to stain finished articles another color. As a rule, coal-tar dyes dissolved in spirit make excellent stains for this material; and for special purposes the following methods are recommended:

Black.—The article is dipped first in weak alkali, then in dilute silver nitrate, and left to dry in the sunlight.

Blue.—A solution of indigo nearly neutralized with potash is used, or a solution of Prussian blue; or a bath of ferric chloride followed, after drying, by one of potassium ferrocyanide.

Brown.—A solution of potassium permanganate, made alkaline with soda, is used.

Green.—The article is dipped in a solution of 2 parts of verdigris and 1 of sal ammoniac.

Red.—The articles are first dipped in water, slightly acidified with nitric acid, and then in an ammoniacal solution of carmine.

Purple.—Immersion in dilute chloride of gold, followed by exposure to strong sunlight.

Yellow.—The article is dipped successively into a solution of lead nitrate and one of yellow chromate of potash.

Hardening and Softening Celluloid

There is no method of hardening celluloid after it is made; if it is required hard, then 3 to 5% of rosin or shellac is mixed with the original pyroxyline for the manufacture of the celluloid. To soften the celluloid and render it flexible castor oil is used. Opaque celluloid may also be made much harder and more like ivory by the addition of mineral matter such as carbonate of lime or zinc oxide.

Polishing Celluloid.—Make a kind of putty of hot soap, free from rosin, in which equal parts of fine pumice stone and flour emery have been mixed.

Printing on Celluloid

1.—For ordinary lettering, etc., or showing up fine colored lines, celluloid may be printed in the usual way. The material, however, has to be specially prepared so as to obtain a matt or rough surface of suitable grain (by handwork, sand-blast or other means), leaving, if necessary, certain parts of the surface intact. The sheet or plate is swilled with water or alcohol, to free the depressions from any clogging, adherent particles, and is then coated with a varnish made of 2 parts of boiled linseed oil, 1 part of white copal varnish, and 1 part of refined ethereal oil, preferably oil of turpentine or lavender. The varnished plate is wiped to force the varnish into the artificial pores of the grain and leave the surface bare, and is then covered for several hours with a mixture of equal parts of finely powdered magnesium and barium sulphates, after removing which it is carefully satined. This treatment gives a surface containing, enclosed in its innumerable fine pores, a very thin, almost transparent layer that exerts chemical attraction on the fatty bodies in printing ink and absorbs and retains them like paper. The most delicate drawings and shades of color can be printed on this surface without risk of running or clogging.

2.—According to F. Meyer celluloid printing is performed as follows: On the one hand, the desired pattern, etc., is printed on paper or like substance, and on the other, the celluloid is moistened with a known solvent, such as alcohol, ether, etc. On pressing the paper and celluloid together a portion of the ink on the former dissolves out and intimately mixes with the dissolved surface of the celluloid, thus forming a waterproof design.

Solvents for Celluloid

Celluloid dissolves in acetone, sulphuric ether, alcohol, oil of turpentine, benzine, amyl acetate, etc., alone, or in various combinations of these agents. The following are some proportions for solutions of celluloid.

1.—Celluloid, 5 grams; amyl acetate, 10 grams; acetone, 16 grams; sulphuric ether, 16 grams.

2.—Celluloid, 10 grams; sulphuric ether, 30 grams; acetone, 30 grams;

amyl acetate, 30 grams; camphor, 3 grams.

3.—Celluloid, 5 grams; alcohol, 50 grams; camphor, 5 grams.

4.—Celluloid, 5 grams; amyl acetate, 50 grams.

5.—Celluloid, 5 grams; amyl acetate, 25 grams; acetone, 25 grams.

Working Celluloid

In general celluloid is worked the same as horn or ivory. In turning the tool should be kept cool with water. In case the work tears, heat the celluloid in water until 90 to 100° F. are reached.

GUTTA PERCHA

1.—Difference Between Gutta Percha and Rubber.—These two substances are constantly confused. A standard work on the subject shows the difference by means of the following comparison in double columns:

INDIA-RUBBER (Gum elastic)	GUTTA PERCHA (Gum plastic)
Raw rubber is soft and malleable when heated, but is still elastic within a certain range of temperature.	In boiling water, becomes plastic and malleable, and if then shaped, preserves its form when cold.
Acted on by air, becomes viscous.	Acted on by air, becomes brittle and resinous, but not so quickly as rubber.
Chief applications are in the sulphur-vulcanized condition.	Will not combine or intimately mix with sulphur.

2.—Bleaching.—Dissolve it in 20 times its weight of boiling benzine, and add plaster of the best quality to the solution, shaking from time to time. In a few days' time the plaster will have settled to the bottom, carrying with it the impurities soluble in the benzine. Decant the liquid and introduce it in small portions into a vessel containing double its volume of 90% alcohol, stirring continually. During this operation the gutta percha precipitates in the form of a perfectly white pastelike mass. The drying of the gutta percha thus purified requires several weeks' exposure to the air; this may be accelerated by triturating it in a mortar, and removing from it the water that separates.

3.—Cementing Cloth, Gutta Percha Tissue for.—Tailors use a special preparation of gutta percha for this purpose, consisting of a thin tissue, placed between layers of the cloth and pressed with a hot iron. Used extensively to fasten the bottom edge of trousers.

4.—Liquid Gutta Percha.—This useful preparation is to be found in the United States Pharmacopoeia, and is made thus: Gutta percha in thin slices, 1 oz.; chloroform, 8 fl.oz.; carbonate of lead, in fine powder, 1 oz. Add the gutta percha to 6 fl.oz. of the chloroform in a stoppered bottle and shake them together frequently until the solution has been effected. Then add the carbonate of lead previously mixed with the remainder of the chloroform, and, having several times shaken the whole together, set the mixture aside and let it remain at rest until the insoluble matter has subsided. Lastly, decant the clear liquid and keep it in a well-stoppered bottle. 1 part of this solution in 10 parts by weight of chloroform produces an excellent and convenient preparation for painting over cuts or wounds. It readily acts as a styptic and protective to the wound and causes neither tension nor pain. If pure iodoform be added, about 10%, it further enhances the value of the styptic and can be used in veterinary surgery with marked success for applying to cuts and abrasions, as it arrests hemorrhage, forms a coating over the wound and promotes a healthy cicatrization.

5.—Melting Gutta Percha.—The gutta percha may be dissolved by adding bisulphide of carbon; if the liquid thus obtained is poured upon glass, after a short time the gutta percha may be lifted in the form of a thin sheet, the bisulphide evaporating very quickly.

6.—Plastic Gutta Percha.—When gutta percha is steeped for a few hours in benzole or naphtha it becomes considerably swollen; if afterward soaked in hot water, it is exceedingly plastic and requires but moderate pressure to obtain most perfect copies from even such fragile objects as plaster-of-paris models.

RUBBER

Belts, Rubber Preservative

Dressing for.—Cut india-rubber into small pieces and dissolve with 5 parts by weight of turpentine oil in a small iron well-covered crucible at a temperature of 50° C. (122° F.) over a coal fire. As soon as the rubber is dissolved, add 4 parts by weight of rosin, stir, remelt, and add in the same way 4 parts by weight of yellow wax. While melting the mixture must be occasionally stirred. Then put 15 parts by weight of fish oil and 5 of tallow into a sufficiently large vessel, heat till the whole is melted, and add the first mixture warm, stirring all the while. Continue stirring till the mass is compact. The dressing should be used in the following manner: If the belts are old and brittle, apply the dressing freely with a brush on both sides in the

sun or in a warm room and leave them to dry. New belts, or belts that are still good, should like the previously treated brittle belts, be lubricated a little on the inside from time to time while in operation; in this way they will be rendered very durable, and will engage well on the pulleys, drums, etc. Cheap, old rubber waste can be used instead of india-rubber; it should first, however, be boiled for a quarter or half an hour in soda lye, and 6½ parts by weight instead of 5 should be taken.

Corks, Rubber, To Cut and Bore

1.—Dip the knife, or cork borer, in solution of caustic potash or soda. The strength is of very little consequence, but it should not be weaker than the ordinary reagent solution.

2.—Alcohol is generally recommended, and it works well until it evaporates, which is generally long before the cork is cut or bored through, and more has to be applied; water acts just as well as alcohol, and lasts longer. When, however, a tolerably sharp knife is moistened with soda lye, it goes through the india-rubber quite as easily as through a common cork; and the same may be said of a cork borer, of whatever size. We have frequently bored inch holes in large caoutchouc stoppers, perfectly smooth and cylindrical, by this method. In order to finsh the hole without the usual contraction of its diameter, the stopper should be held firmly against a flat surface of common cork until the borer passes into the latter.

Covering Cloth with Rubber

To cover cloth with rubber, naphtha, alcohol and benzole are chiefly employed for dissolving the rubber. They are mixed with purified solid paraffine and ground together.

Deodorizing Rubber

1.—Place the articles, covered with charcoal dust, in an enclosed vessel, let them remain for several hours at a temperature of 94° F. Clean the charcoal dust from the articles; they will be odorless.

2.—Caustic potash, ½ oz.; water, 1½ pt.; dissolve and heat to boiling. Put the goods into this for a few minutes, rinse thoroughly and dry.

3.—Both sides of the article should be covered with a thin layer of animal charcoal. Heat for 3 or 4 hours from 122 to 140° F.

4.—Equal parts of alcohol, 36%, and linseed oil, shaken together thoroughly. Apply to the hose with a cloth. Stretch the hose a little, and rub until nearly dry. Repeat 3 or 4 times at intervals of several days. This treatment renders the hose gastight.

5.—Treat the rubber with solutions of caustic potash or caustic soda; treatment with potash or soda, since caustic potash and caustic soda injure the rubber; boil with alkaline soaps; boil with lescive phenix—calcined soda with water glass; and lastly, after treatment with soda, leave the rubber for some time in a solution of cooking salt (10 to 15%).

Dissolving Rubber

The solution of india-rubber or gutta percha in chloroform or benzole, frequently called for in photographic work, is usually attended with so many difficulties and drawbacks that in nine cases out of ten where the solution is required the experimentalist usually purchases it ready made. Yet there need be no difficulty about the matter. First, pure rubber should be obtained. When vulcanized, it is perfectly insoluble. Secondly, pure solvents are necessary. Chloroform containing a large excess of alcohol and water will fail to act even upon the purest rubber. Again, under the most satisfactory conditions, the action is very slow, and the amount of rubber capable of being taken up is proportionately very small. The plan usually adopted is to place a large amount of shredded rubber in a bottle, which is then filled up with the solvent, and shaken at intervals a few times; and when the shreds do not dissolve like pieces of sugar the whole is thrown aside, and we are written to for an explanation of the failure. If a small quantity of rubber had been placed in the bottle, and the liquid added, it would have been observed gradually to swell out very considerably after the lapse of some time, and a mixture of the whole would be facilitated by stirring with a glass rod or a splinter of wood. The rapidity with which the rubber absorbs the solvent will depend upon its condition; but the action is never very quick, nor is it in any way analogous to the dissolution of a crystal. One cause of the failure of chloroform to act upon the caoutchouc may arise from the presence of alcohol in too great a proportion. Chloroform as sold almost always contains alcohol in small quantity, owing to the fact that when none is present it cannot be prevented from decomposing spontaneously, more especially in the light. It is, however, stated that when entirely protected from light absolute

chloroform will not undergo any change. A solution of gutta percha in chloroform has a use which is not generally known. It forms, when carefully made and filtered quite bright, the best possible material for obscuring glass for focussing screens. For fine microscopic work it is said by those whose opinions are of weight to be unequaled.

Durability of Rubber Goods, To Increase

A great disadvantage of rubber goods consists in their becoming brittle or sticky very quickly. For the purpose of rendering them soft and elastic again, prepare a moderately strong solution of alum in water, into which lay the rubber articles for a day or two; after that time they are no longer hard or sticky. It is of great advantage for all rubber goods, if seldom used, to be kept in clean water; this will greatly increase their durability. If the objects are not easily placed under water, as for instance, bicycle tires and similar bulky pieces, it is well to wash them from time to time with water to prevent them from becoming too dry. In this connection it is well to mention that it is harmful for the tires to be tightly inflated over winter and the rubber to touch the floor; the bicycle should rest on a stand or be suspended. Moreover, it should be kept in a dark room in as even a temperature as possible, or at least be provided with a covering of cloth, since air and light exercise an equally destructive action upon rubber.

Ebonite and Vulcanite

These two materials are practically the same substance, the main difference being in the coloring materials used. They consist of india-rubber and sulphur, practically the same as vulcanized india-rubber, but a great heat, and time, are employed to vulcanize the compound. To prepare it as sold in the form of combs, toilet and fancy articles, the rubber is worked in a masticating machine with the proper quantity of sulphur, and when thoroughly mixed a sufficient quantity is put into a mold of the right shape made of plaster of paris, or other material which will not combine with sulphur, and exposed in a steam boiler to a heat of 315° F., and a pressure of about 12 lb. to the inch for 2 hours. It is then removed from the mold, and finished, and polished exactly in the same manner as ivory. The application of heat as above without a steam pressure is sufficient to vulcanize or harden the compound, but the result is not always so satisfactory, as the material is liable to be porous, if not compressed while hardening. Gutta percha may be treated in exactly the same manner as rubber, and cannot be distinguished from it, but is rather more troublesome to work. The vulcanite may be turned or carved in the same way as ivory, with the advantage that it may be molded to the required form without the great waste which attends ivory carving. It is also much less liable to fracture. The smaller the proportions of sulphur in the rubber, and the lower the temperature used, the softer and more elastic will be the rubber. About 10 or 15% of sulphur and a temperature of 270 to 275° F. for 4 hours, will make an elastic rubber; 30% of sulphur and a temperature of 315° F. for 2 hours will make a hard vulcanite like ivory.

Ebonite.—1.—Sulphur, 2 to 3 parts, is mixed with caoutchouc, 5 parts, and cured for several hours at 75° C., under a pressure of 4 to 5 atmospheres. Ebonite is apt to become porous and conductive in moist air or in sunlight. It keeps best when dry and in the dark. Heat softens and deforms it. To prevent loss of insulation by oxidation of the sulphur, the surface should be washed from time to time with boiling water, then rinsed with distilled water, and dried. The surface should be shellaced or paraffined, especially in moist climates.

2.—Hard Good Quality.—Best Para rubber, 2 parts; sulphur, 1 part, by weight.

3.—American Ebonite.—Rubber, 12 parts; sulphur, 8 parts; whiting, 1 part; wash, 1 part, by weight. Curing molds for above; lead, 2 parts; antimony, 1 part, by weight.

4.—Hints on Working Ebonite.—a.—The following are useful hints, which appeared in the American Machinist, relating to the working of ebonite:

The best qualities show on fracture a brightness something of the nature of jet, and the poorer sorts a corresponding dullness. Although an apparently easy material to machine, its wearing effect on cutting tools is comparatively great. In sawing, turning, planing, or milling, the best speed is that at which brass is machined, and milling should always be accompanied by the free use of soap and water, having regard to the fact that a milling cutter is an expensive tool; but for turning or sawing, lubricants are in the way, on account of the spattering round of ebonite cuttings and soapy water.

b.—Turning.—When turning ebonite it is always preferable to leave the tools dead hard with a lot of "rake" on, and to

take as deep a cut as possible, with a slow feed. Herein will be found the advantage of the tool-holder system for turning tools, in which the cutter can be taken out and replaced by a fresh one, saving thereby a good many journeys to the grindstone; for the moment a cutter becomes dull, which is frequent, instead of cutting it "burns" the surface of the material, and, of course, militates against the production of good work.

c.—Lubricants.—When tapping ebonite soft soap has been found to be the best lubricant.

Oil should never be used as it works into the material and in time rots the thread. Taps made of rod brass will be found useful, for if a dozen or two holes are executed with an ordinary tap, it will be comparatively useless on metal. Brass taps are easily made, and last almost as well as steel. Reamers of brass can be used in the same manner; an ordinary nose type with four saw-slits made in the end, and a tapped hole admitting a taper screw for expanding the tool as it becomes worn, is as handy and as cheap a method of reaming holes in ebonite as the writer knows of. When worn, it can be headed up easily and made ready for use again. In shops where ebonite is used it is nearly always found necessary to do a lot of sawing, and it will be found best not to use expensive tools. Good saws—properly ground for clearance—are often rendered useless after a day's work on this material, and home-made sheet-steel saws are as good as the most expensive ones for cutting, besides being more readily sharpened, the necessary clearance being given to them by setting the teeth over sideways. Although of a brittle nature, the thinnest sheets can be worked in the press up to a thickness of about .02 in., keeping the tools and materials warm by means of a gas-jet, and, although the stampings come out rather rough on the edges, they will be found suitable for jobs where a smooth edge is not desired.

d.—Polishing.—In polishing ebonite, after taking all tool-marks out with emery paper (commencing with F.F. and finishing with No. 1 blue-black French paper), a lap of hard felt charged with bath brick and oil is used, after which another lap charged with rotten stone and oil will be found to give good results; at the same time taking care not to exercise too much pressure, for an excess of friction "burns" the surface of the ebonite, rendering it incapable of taking a high polish. If a dead finish is desired, all that is necessary, after using the emery cloth, is for the surface to be rubbed over with a cloth dampened in paraffine.

Vulcanite.—1.—About equal parts of rubber and sulphur are used, to which is added about 7 to 10 per cent. of lampblack. These are all worked together in the masticating machine. A very useful vulcanizer for small goods is that made for dental work. It usually takes the shape of a cylindrical iron vessel with bolted-on lid, and fitted with a pressure gauge, thermometer, and safety valve. Perforated divisions are put inside for the articles to rest on. With the simple vulcanizers the required heat is obtained by putting a little water in the bottom of the vessel, then lighting a burner underneath to create steam which soon reaches a high pressure and temperature. The safety-valve is set to blow off at the proper pressure. Larger vulcanizers are steam-jacketed, which is no advantage except where high-pressure steam is available. The heat for vulcanizing should be slowly raised, the whole process being extended to about 4 hours, the final and highest temperature being 150° C. (302° F.). In large works the vulcanizing chamber is a horizontal cylindrical oven with a door in one end, free high-pressure steam being used, supplied to the interior (without a jacket). It may be explained that the pressure and temperature of steam go together, and for 302° F. the steam pressure would be 55 lb. on the gauge.

2.—(Of Gitschin.)—Thirty-six parts of nitrate of potash, 19 parts nitrate of soda, 11 parts sulphur, 9 parts sawdust, 9.5 parts chlorate of potash, 6 parts wood-charcoal, 4.5 parts Glauber's salt, 2.25 parts red prussiate of potash, 2.35 parts sugar, 1.25 parts picric acid.

3.—Polishing. — a.—Remove scratches with a smooth wet water-of-Ayr stone, and then polish in the lathe with fine pumice and a stiff brush. After washing the pumice off, polish it with whiting and soft brush.

b.—The mathematical instrument makers treat it as brass—that is, for flat work they first use water-of-Ayr stone, and then rotten stone and oil. Turned work is polished in the lathe with rotten stone and oil, taking care not to use too high a speed, which would heat the work. Some use lampblack and oil to finish with where a very high polish is wanted, or the bare palm of the hand, as in getting up silver plate. Chain and ornament work, made of seahorse-leather, and for work of irregular forms, buffs of calico. A number of pieces of calico, 12 in. in diameter, are screwed together between flanges, like a circular-saw spindle, and used with rot-

ten stone, always taking care not to heat the work; brushes are not at all suitable for it.

c.—To polish turned vulcanite which has been finished with a scraping tool, take a handful of vulcanite shavings, and apply these as the article revolves. Next prepare a piece of soft linen (a surgical bandage will do) by soaking in any sort of common oil, and sprinkle one side with putty powder (oxide of tin), then loop the prepared side round the article, holding the ends firmly with both hands, and work it evenly all over the article while the lathe is running, and finish the polishing in the same manner with a clean piece of linen without polishing medium.

4.—Soft Vulcanized India Rubber.—Para rubber, 7.5 parts; sulphur, 0.75 part; lime, 0.01 part; whiting, 7.5 parts; French chalk, 1.25 parts; litharge, 1.5 parts, by weight.

5.—Vulcanizing Rubber. — Parkes' method is now sometimes adopted. The caoutchouc is immersed in a mixture of 39 parts of bisulphide of carbon and 1 part of chloride of sulphur. It is next placed in a room heated to 70° F., and when all the sulphide of carbon has been volatilized, the process is so far complete that it is only requisite to boil the material in a solution of about 18 oz. of caustic potassa to 2 gal. of water, the vulcanized caoutchouc being next washed to remove excess of alkali.

6.—Working Vulcanite.—Vulcanite can be worked with ordinary wood-cutting, sawing or turning tools, as it works much like ivory. It is desirable to keep vulcanite cool when working it, as it heats rapidly and softens with heat. At the boiling point of water vulcanite can be bent and, when cold, will retain its new shape. At a little higher temperature vulcanite is soft enough to be impressed with a pattern, or to be molded.

Joining Rubber

Rubber is easily joined, and made as strong as an original fabric, by softening before a fire, laying the edges carefully together, without dust, dirt, or moisture between. The edges so joined must be freshly cut in the beginning. Tubing can be united by joining the edges around a glass cylinder, which has previously been rolled with paper. After the glass is withdrawn the paper is easily removed. Sift flour or powdered soapstone through the tube to prevent the sides from adhering from accidental contact.

Repairing

1.—Hose.—Fill the cracks previously cleaned with the following solution: 20 parts of gutta percha, 40 parts of caoutchouc, 10 parts of isinglass, 160 parts of sulphide of carbon. Very wide, gaping slits may be plastered with the solution in layers and the slit drawn together with a string. Allow 1 to 2 days for drying. Then the string can be cut through and the protruding cement trimmed off with a sharp knife, that has previously been dipped in water.

2.—Pads and Covers.—a.—Before the patching, the cracked surfaces to unite well must be dried, entirely freed from all dirt and dust and greased well, otherwise the surfaces will not combine.

b.—In case of a cover, waterproof coat, or rubber boots, etc., take a moderately thick piece of india-rubber, suited to size of the object, cut off the edges obliquely with a sharp knife moistened in water, coat the defective places as well as the cut pieces of rubber with oil of turpentine, lay the coated parts together and subject them for 24 hours to a moderate pressure. The mended portion will be just as waterproof as the whole one.

c.—Rubber cushions or articles containing air are repaired in a very simple manner, after being cleaned as aforesaid. Then take colophony, dissolve it in alcohol (90%) so that a thick paste forms, smear up the holes, allow all to harden well, and the rubber article, pillow, ball, knee caps, etc., may be used again.

Solvents

1.—The best solvent and perhaps the most rapid consists of a mixture of methylated ether and petroleum spirit—the common benzoline used for burning in sponge lamps. The mixture is as much superior in power to either of its constituents singly as the ether-alcohol is to plain ether in its action on pyroxyline.

2.—A very thick solution can be made by dissolving 60 gr. of good india-rubber in 2 oz. of benzoline and 1 oz. of sulphuric ether. If the india-rubber be cut up fine and the mixture shaken occasionally, the solution will be complete in two or three hours, when it may be diluted to any required strength with benzoline alone. The india-rubber should be as light-colored as possible, and all the outer oxidized portions must be cut away. Shred the clean india-rubber with a pair of scissors, and throw it at once into the solvent.

Sponge, Rubber

The uses to which sponge rubber are put are many and varied. It is used as a cushion for rubber stamps, in artificial feet, in playing balls, in semi-solid tires,

for erasive rubber, for glove-cleaners, and it has been tried in horse collars, harness pads, cushions, and so on. In all cases the sponginess is induced by incorporating something that will give off vapors during the process of cure. The very cheapest liquid for this purpose is water; hence one of the first compounds for puff balls depended upon its dampness for sponging. It was as follows:

1.—Soft African rubber, 5 lb.; reclaimed rubber, 5 lb.; whiting, 6 lb.; litharge, 2 lb.; palm oil, 1 lb.; sulphur, 5½ oz.; damp sawdust, 2 lb. The sawdust was just fine enough to pass through a sieve of No. 20 mesh. It was thoroughly wet and the mixing done on a cool mill. A slow cure and the cooling of the molds before opening are of course necessary.

2.—Compounds similar to the above where fiber, substitute, etc., are made the means of carrying the water are very common and are exactly as good for the purpose. Quite a variety of ingredients are used in some of the spongy compounds. but none will appear to the rubber manufacturer to be more novel than brown sugar and licorice, both of which bring about sponginess. Perhaps the most distinctively "freak" compounds in this line are those that follow, and have been the subjects of British patents:

a.—Para rubber, 50 lb.; tungstate of soda, 9 lb.; alum, 2 lb.; carbonate of ammonia, 14 lb.; asbestos (fine powder) 28 lb.; arsenic, 1 lb.; gum kauri, 1 lb.

Varnishes for Rubber

India-rubber Varnish.—1.—An excellent and rapidly drying waterproof varnish is prepared in the following manner: Heat a weighed quantity of boiled linseed oil until it fumes strongly. A vessel with plenty of extra room in it must be used. Have ready some india-rubber cut small, and 1 oz. of it for every pound in the original weight of the oil. When one piece thrown in melts at once, put in the rest gradually, and when all is melted stop the heating. When cold dilute the varnish with turps to the required consistency.

2.—Dissolve 10 lb. of india-rubber in 10 lb. of turpentine and 20 lb. of petroleum by treating same on a water bath. When the solution is completed add 45 lb. of drying oil and 5 lb. of lampblack and mix thoroughly.

3.—Dissolve 7 lb. of india-rubber in 25 lb. of oil of turpentine. By continued heating dissolve 14 lb. of rosin in the mixture. Color white hot with 3 lb. of lampblack.

CHAPTER XI.

SOLDERS AND SOLDERING

SOLDERING FLUIDS, FATS, PASTEES AND POWDERS.

The Soldering of Metals and the Preparation of Solders and Soldering Agents.—The object of soldering is to unite two portions of the same metal or of different metals by means of a more fusible metal or metallic alloy, applied when melted, and known by the name of solder. As the strength of the soldering depends on the nature of the solder used, the degree of strength required for the joint must be kept in view in choosing a solder. The parts to be joined must be free from oxide and thoroughly clean; this can be secured by filling, scouring, scraping, or pickling with acids. The edges must exactly fit, and be heated to the melting-point of the solder. The latter must have a lower melting-point than either of the portions of metal that require to be joined, and if possible only those metals should be chosen for solder which form alloys with them. The solder should also as far as possible have the same color and approximately the same strength as the article whose edges are to be united.

To remove the layers of oxide which form during the process of soldering, various so-called "fluxes" are employed. These fluxes are melted and applied to the joint, and act partly to keep off the air, thus preventing oxidation, and partly reduce and dissolve the oxides themselves. The choice of flux depends on the quantity of heat required for soldering.

Solders are classed as soft and hard solders. Soft solders, also called tin solders, or white solders, consist of soft, readily fusible metals or alloys, and do not possess much strength; they are easy to handle on account of their great fusibility. Tin, lead-tin and alloys of tin, lead, and bismuth are used for soft solder, pure tin being employed only for articles made of the same metal (pure tin).

The addition of some lead makes the solder less fusible but cheaper, while that of bismuth lowers the melting-point. Soft solders are used for soldering easily fusible metals such as Britannia metal, etc., also for soldering tin-plate. To prepare solder, the metals are melted together in a graphite crucible at as low a temperature as possible, well stirred with an iron rod, and cast into ingots in an iron mold. To melt the solder when required for soldering, the soldering iron is used; the latter should be kept as free from oxidation as possible, and the part applied should be tinned over.

The fluxes generally used in the soft-soldering of metals are powdered rosin or a solution of chloride of zinc, alone or combined with sal ammoniac.

Soldering Fluids, Antacid.—1.—A neutral soldering liquid can be prepared by mixing 27 parts neutral zinc chloride, 11 parts sal ammoniac and 62 parts water, or 1 part sugar of milk, 1 part glycerine, and 8 parts water.

2.—Into an earthenware cup pour some commercial muriatic acid, into which put small pieces of scrap zinc. Let one piece dissolve or nearly so before another is put in, as otherwise the acid gets very hot, and is liable to break the jar. Always put more in than the acid will dissolve. Then let it stand for twenty-four hours. Now pour half of this into a small bottle with a wide mouth, and dilute with an equal volume of water, and filter. Add liquid ammonia by the drop until the precipitate formed in the beginning dissolves again. Apply with a stick or small brush. Use what remains in the jar to clean the iron after each heating, by dipping the whole pointed end thereof into the liquid. This flux may be used on almost any metal except aluminum, zinc or galvanized iron. For the two last named the commercial acid should be used; for galvanized iron wire use 3 parts lead and 1 part zinc.

If the shape of the article to be soldered does not admit of the use of liquid soldering water, mix the solution of ammonia-zinc chloride with starch until a syrupy liquid is obtained.

3.—If the above are not within the reach of the user, a serviceable soldering liquid may be formed by mixing together 1 part of lactic acid, 1 part of glycerine, and 3 parts of water.

4.—Silver, Anti-oxidizer for.—A wash of a paste of whiting and water dried on the bright parts of jewelry or silverware

will save it from oxidation while soldering, but must not interfere with the boraxed joint to be soldered.

Fats.—Soldering fat or grease is commonly a mixture of rosin and tallow with the addition of a small quantity of sal ammoniac. It is particularly adapted to the soldering of tinned ware, because it is easily wiped off the surface after the joint is made, whereas if rosin were used alone, the scraping away might remove some of the tin and spoil the object.

1.—In a pot of sufficient size and over a slow fire melt together 500 grams of olive oil and 400 grams of tallow; stir in slowly 250 grams of rosin in powder, and let the whole boil up once; let it cool down, and add 125 grams of saturated solution of sal ammoniac, stirring the while. When cold, this preparation will be ready for use.

2.—Soldering fat for aluminum is made by melting together equal parts of rosin and tallow, half the quantity of zinc chloride being added to the mixture.

Paste.—Mix starch paste with a solution of tin chloride to produce a liquid about the consistency of syrup. This is more readily applied than ordinary soldering liquid.

Powders.—1.—Borax is the flux most frequently used for hard soldering. It should be applied to the soldering seam either dry or stirred to a paste with water. When used direct the process is somewhat difficult. The parts must be carefully

TABLE OF SOLDERS

Name.	Composition.
Soft, coarse	Tin, 1; lead, 2
Soft, fine	Tin, 2; lead, 1
Soft, fusible	Tin, 2; lead, 1; bis., 1
Pewterer's	Tin, 3; lead, 4; bis., 2
Spelter, soft	Copper, 1; zinc, 1
Spelter, hard	Copper, 2; zinc, 1
Silver, fine	Silver, 66.6; copper, 23.4; zinc, 10
Silver, common	Silver, 66.6; copper, 30; zinc, 3.4
Silver, for brass and iron	Silver, 1; brass, 1
Silver, more fusible	Silver, 1; brass, 1; zinc, 1
Gold, for 18 carat gold	Gold, 18 carats fine, 66.6 Silver, 16.7; copper, 16.7
Gold, more fusible	Same as above with a trace of zinc
Platinum	Fine gold

Material to be Soldered.	Solder.	Flux.
Tin	Soft, coarse or fine	Rosin or zinc, chl.
Lead	Soft, coarse	Rosin
Brass, copper, iron and zinc	Soft, coarse	Zinc, chl.
Pewter	Pewterer's or fusible	Rosin or zinc, chl.
Brass	Spelter, soft	Borax
Copper and iron	Spelter, soft or hard	Borax
Brass, copper, iron, steel	Any silver, S.	Borax
Gold	Gold, S.	Borax
Platinum	Fine gold	Borax

No.	Name.	Composition.	Flux.	Fluxing point.
1.	Plumbers' coarse solder	Tin, 1; lead, 3	R	800° F.
2.	Plumbers' sealed solder	Tin, 1; lead, 2	R	441° F.
3.	Plumbers' fine solder	Tin, 1; lead, 2	R	370° F.
4.	Tinners' solder	Tin, 1½; lead, 1	R or Z	334° F.
5.	Tinners' fine solder	Tin, 2; lead, 1	R or Z	340° F.
6.	Hard solder for copper, brass, iron	Copper, 2; zinc, 1	B	....
7.	Hard solder for copper, brass, iron	Good tough brass, 5; zinc, 1	B	....
8.	Hard solder for copper, brass, iron, more fusible than 6 or 7	Copper, 1; zinc, 1	B	....
9.	Hard solder for copper, brass, iron	Good tough plate brass	B	....
10.	Silver solder for jewelers	Silver, 19; copper, 1; brass, 1	B	....

TABLE OF SOLDERS—(*Continued*)

No.	Name.	Composition.	Flux.	Fluxing point.
11.	Silver solder for plating	Silver, 2; brass, 1	B	....
12.	Silver solder for silver, brass, iron	Silver, 1; brass, 1	B	....
13.	Silver solder for steel joints	Silver, 19; copper, 1; brass, 1	B	....
14.	Silver solder, more fusible	Silver, 5; brass, 5; zinc, 5	B	....
15.	Gold solder	Gold, 12; silver, 2; copper, 4	B	....
16.	Bismuth solder	Lead, 4; tin, 4; bismuth, 1	R or Z	320° F.
17.	Bismuth solder	Lead, 3; tin, 3; bismuth, 1	R or Z	310° F.
18.	Bismuth solder	Lead, 2; tin, 2; bismuth, 1	R or Z	292° F.
19.	Bismuth solder	Lead, 2; tin, 1; bismuth, 2	R or Z	236° F.
20.	Bismuth solder	Lead, 3; tin, 5; bismuth, 3	R or Z	202° F.
21.	Pewterers' solder	Lead, 4; tin, 3; bismuth, 2	R or Z	

Abbreviations: R, rosin; B, borax; Z, chloride of zinc.

BRASS SOLDERS

	Copper.	Zinc.	Tin.	Lead.	Color.
Very strong	58	42	...	...	Reddish yellow
Strong	53	47	...	...	Reddish yellow
Medium	50	50	...	...	Reddish yellow
Medium	54½	43½	1½	½	Reddish yellow
Easily fusible	34	66	...	...	White
Easily fusible	44	50	4	2	Gray
White solder	57	28	15	...	White

The best solder for platinum is fine gold. The joint is not only very infusible, but it is not easily acted upon by common agents. For German silver joints an excellent solder is composed of equal parts of silver, brass and zinc. The proper flux is borax.

SOLDERS FOR SPECIAL PURPOSES

Solders.	Gold.	Silver.	Copper.	Tin.	Zinc.	Lead.	Bismuth.	Brass.	Melting point.
Pewterer's	..	..	..	2	..	1	2	..	360°
Pewterer's, soft	..	..	..	3	..	4	1	..	....
Pewterer's, soft	..	..	..	2	..	1	..	..	....
Tinman's	..	..	..	1	..	1	..	..	393°
Coarse	..	..	..	1	..	3	..	..	500°
Plumber's	..	..	..	1	..	2	..	..	475°
Hard spelter	..	..	4	..	3	..	..	..	1,869°
Gold	6	1	2	..	..	..	..	..	....
For brazing steel	..	19	1	..	..	..	..	2	....
Hardest silver	..	4	1	..	..	..	..	..	....
Hard silver	..	3	..	..	..	..	..	1	....
Soft silver	..	2	..	..	..	..	..	1	....
For aluminum	..	2	..	2	1	2	..	..	....

WHITE SOLDERS FOR GOLD WORK

No.	Name.	Fine silver. Parts.	Copper. Parts.	Spelter. Parts.	Fusing point.
1.	Hard solder	16	3½	½	1,866° F.
2.	Medium	15	4	1	1,843° F.
3.	Easy	14	4½	1½	1,818° F.
4.	Common hard	12½	6	1½	1,826° F.
5.	Common easy	11½	6½	2	1,802° F.

COLORED SOLDERS FOR GOLD WORK

No.	Name.	Fine gold. Parts.	Fine silver. Parts.	Shot copper. Parts.
1.	Best gold solder	12½	4½	3
2.	Medium gold solder	10	6	4
3.	Common gold solder	8½	6½	5

SILVER SOLDERS

No.	Name.	Fine silver. oz.	dwt.	Shot copper. dwt.	gr.	Brass. dwt.	gr.	Zinc. dwt.	gr.	Arsenic. dwt.	Compo. dwt.	gr.
*1.	Hardest—Silver, solder	1	0	5	0	..	..	..	..	..	..	..
2.	Hard	1	0	..	..	6	16	..	..	..	..	..
3.	Easy i.e.	1	0	..	..	10	0	..	..	..	..	..
4.	Best hard	1	0	4	9	..	..	0	15	..	..	..
5.	Medium	1	0	5	8	..	..	1	8	..	..	..
6.	Easy	1	0	6	12	..	..	2	4	..	..	..
7.	Common	1	0	9	15	..	..	2	9	..	..	..
8.	Enameling	1	0	5	0	..	..	..	..	..	..	..
*9.	Enameling	1	0	10	0	..	..	..	..	..	..	..
*10.	Filigree	0	16	0	12	..	..	..	..	..	3	12
11.	Quick running	1	0	..	..	..	..	..	..	20	10	0
*12.	Chain	1	0	10	0	..	..	2	0	..	..	..
13.	Easy chain	1	0	..	..	..	..	2	0	..	10	0
*14.	Common	1	0	12	0	..	..	3	0	..	..	..
15.	Common easy	1	0	..	..	..	..	3	0	..	12	0
16.	Very common	1	0	..	..	..	..	..	..	1 oz.	1 oz.	

*Silver solders recommended for special work.

cleaned each time prior to applying the salt. The salt in contact with the soldering iron forms great bubbles, and easily scales away from the surface of the parts to be soldered. It is advisable to use calcined borax; *i.e.*, borax from which the water of crystallization has been driven out by heat, as it does not become so inflated as ordinary borax. Borax dissolves the metallic oxides forming on the joint.

To avoid the difficulty mentioned, instead of borax use its component parts, boric acid and sodium carbonate. The heat of the soldering iron acting upon them produces an excellent flux.

2.—Mix equal parts of neutral zinc chloride, free from iron, and powdered sal ammoniac. To use, dissolve 1 part of the salt in 3 or 4 parts of water.

3.—For hard-soldering aluminum bronze use a mixture of equal parts of cryolite and barium chloride as a flux.

4.—For hard-soldering copper and copper alloys use finely powdered cryolite, or a mixture of 2 parts powdered cryolite and 1 part phosphoric acid.

5.—For soldering iron with cast iron use a flux composed of equal parts of cast-iron filings and calcined borax. Pulverize this black, glassy mixture, and spread the powder on the seam.

6.—For soldering steel, melt in an earthen vessel 3 parts of borax, 2 parts of colophony, 1 part of carbonate of potash, 1 part powdered hard soap to which 3 parts of pulverized glass and 2 parts of steel filings have been added. Run the melted mass on cold sheet iron. When completely cooled, break in pieces and grind fine. Apply to the surfaces to be joined a few minutes before uniting them.

DETAILED FORMULAS FOR SOLDERS

Soft Solders

Soft solder, or tin solder, can be used to solder many different metals, gold, silver, lead, copper, and steel, as well as brass, wrought iron and zinc. Its principal use, however, is in ordinary tinsmith's work, for which tin plate, zinc and sheet brass are the materials most frequently employed. Soft solder can be used for any purpose where the soldered articles need not be heated much above

the boiling point of water, so that there is no danger of its melting.

For ordinary tinsmith's work, where the resistance of the solder to acids, etc., is of less importance, it is customary to use mixtures of tin and lead, in varying proportions according to different purposes and according to the required melting point of the solder. Experts have taken much pains to make accurate determinations in this important matter, and the following table gives the fusing point (Centigrade) of a solder containing a given amount of lead to 100 parts of tin:

Lead.	Fusing Point, Deg. C.	Density of the Alloy.
16.5	194	7.927
30	194	7.994
33.3	194	8.109
40	194	8.234
45	187	8.267
50	187	8.408
60	181	8.447
66.6	181	8.726
100	197	8.864
119	197	9.038
125	210	9.270
179	210	9.433
200	235	9.554
233	235	9.640
250	235	9.770
268	243	9.797
300	246	9.939
358	246	10.052
536	270	10.331
715	283	10.595
880	292	10.751
1072	292	10.815

It will be seen that the alloys of tin and lead become denser and less readily fusible as the contents of lead are increased. According to other experiments, the fusing points of the alloys are as given below:

Lead.	Tin.	Fusing Point. Deg. C.
207	118	189
207	354	180
207	708	190
621	236	211
1242	118	270

Before the solders really melt, they soften considerably, and the following table gives the softening point of some alloys:

Lead.	Tin.	Softening Point, Deg. C.	Melting Point, Deg. C.
1035	236	185	189
1242	236	189	194 to 195
1449	236	192	198
1656	236	202	208 to 210

Alloys Used Specially for Solders:

Tin.	Lead.	Fusing Point, Deg. C.
1180	4140	240
1180	3105	223
1180	2070	200
1180	1242	181
1180	1035	185
1180	828	190

Composition of Ordinary Soft Solder.—Lead, 207; tin, 118.

Weak Soft Solder.—Lead, 207; tin, 236.

Strong Soft Solder.—Lead, 414; tin, 118.

Fluid Solder.—Lead, 621; tin, 590.

Fluid solder is prepared by making the given mixture and letting it stand until partially hardened, when the part which is still fluid is poured off. In using this, it is poured into large seams, and works extremely well. The stiffened part can be used as ordinary solder.

If the alloys are to be made in small quantities, it requires very sensitive scales to weigh the metals accurately. The composition of some varieties of tin solder is given below, in round numbers, with the fusing point of each. They are numbered according to their fluidity. No. 1 being the hardest.

1.—Lead, 2; tin, 1. Fusing point, 240° C.

2.—Lead, 1; tin, 1. Fusing point, 200° C.

3.—Tin, 2 to 2½; lead, 1. Fusing point, 185 to 190° C.

4.—Lead, 10; tin, 177. Fusing point, about 180° C.

Bismuth Solder.—For some purposes even the soft solders of tin and lead are too difficult of fusion, and in this case alloys of tin, lead, and bismuth are employed. This is a most excellent solder, but its use is limited to very special purposes, on account of the expensiveness of bismuth. For ordinary work, also, there is no need of such an extremely low fusing point. (See Fusible Metals in chapter on ALLOYS.)

Hard Solders

In treating of soft solders, it was shown that the fusing point of these compositions varies considerably. The variations are still greater in the case of hard solders, whose composition is such that they melt only on being brought to strong red heat. Some of them can be melted in the ordinary way, with the aid of a soldering iron, while in the case of others,

a special apparatus, such as a bellows, must be employed, or the whole object to be soldered must be strongly heated. The numerous kinds of hard solders, with different fusing points, are made necessary by the difference in the nature of the various metals and metallic compositions which may require soldering.

Yellow Hard Solders.—1.—Very Hard. —a.—Applebaum's Compositions.—1.—Copper, 58; zinc, 42.

b.—Sheet brass, 85.42; zinc, 13.58.

c.—Karmarsch's Composition.—Brass, 7; zinc, 1.

d.—Prechtl's Composition.—Copper, 53.30; zinc, 43.10; tin, 1.30; lead, 0.30.

2.—The foregoing compositions have the yellow color of brass, are very strong, and require very high temperatures for melting, so that they can be used for copper, steel, and all kinds of iron. The ones next given melt more easily than the first, and are suitable for all kinds of work with brass.

a.—Sheet brass, 81.12; zinc, 18.88.

b.—Copper, 54.08; zinc, 45.29.

c.—Brass, 3 to 4; zinc, 1.

d.—Brass, 78.26; zinc, 17.41; silver, 4.33. This is somewhat expensive on account of the silver, but has the valuable property of being at once tenacious and ductile, and can be worked into wire with hammer or rollers.

3.—Still softer are: a.—Brass, 5; zinc, 2.5.

b.—Brass, 5; zinc, 5.

Half White.—1.—Copper, 53.3; zinc, 46.7.

2.—Brass, 12; zinc, 4 to 7; tin, 1.

3.—Brass, 22; zinc, 10; tin, 1.

4.—Copper, 44; zinc, 49; tin, 3.20; lead, 120.

1 (Volk's hard solder) and 4 (Prechtl's half white) are quite readily fusible.

White.—1.—Brass, 20; zinc, 1; tin, 4.

2.—Brass, 11; zinc, 1; tin, 2.

3.—Brass, 6; zinc, 4; tin, 10.

4.—Copper, 57.44; zinc, 27.98; tin, 14.58.

Solders Prepared from the Pure Metals.

	Copper.	Zinc.	Tin.	Lead.
Very hard	59.94	42.06	.....	.....
Very hard	58.33	41.67	.....	.....
Hard	50.00	50.00	.....	.....
Soft	33.34	66.66	.....	.....
Soft, half white	44.00	49.90	3.30	1.20
Soft, white	57.44	27.98	14.58	.....
Soft	72.00	18.00	4.00	.....
Soft, Volk's	53.30	46.70	.....	.....

Solders of Brass and Zinc.

	Brass.	Zinc.	Tin.
Very hard	85.42	12.58	.....
Very hard	7.00	1.00	.....
Hard	3.00	1.00	.....
Hard	4.00	1.00	.....
Soft	5.00	2.00	.....
Soft	5.00	4.00	.....
Half white	12.00	5.00	1.00
Half white	44.00	20.00	2.00
White	40.00	2.00	8.00
White	22.00	2.00	4.00
White	18.00	12.00	30.00
Very ductile	78.25	17.25	.....
For brazier's work	81.12	18.88	.....

Brass Solders.

Yellow, hard	53.30	43.10	1.30	0.30
Half White, soft	44.00	49.90	3.30	1.20
White	57.44	27.98	14.58	.....

German Silver Solders

The solders thus classified, as their name implies, are used principally for soldering German silver. This alloy contains nickel and is very hard and white, and it requires solders which have corresponding qualities. German silver belongs among the alloys which are very difficult of fusion, and the solders used for it are those which have very high fusing points, and belong therefore to the general class of hard solders. They have great strength, and are used for other purposes, in cases where the object to be soldered is exposed to heavy strain. German silver solder can be given a color very much like that of steel, and is much used in steel work.

In regard to its composition, it bears this relation to ordinary hard solders, that while these may be considered to be brass with an admixture of zinc, German silver solder may be called a mixture of zinc and German silver solder. It is softer or harder according to the greater or less amount of zinc contained in it; but if this exceeds a certain limit, the solder becomes very brittle.

There are two principal varieties of German silver solder, called, relatively, hard and soft. The former is exceedingly strong, on account of the large amount of nickel it contains, and is sometimes called "steel solder," being generally used for soldering steel.

Soft German Silver Solders.—1.—Copper, 4.5; zinc, 7.0; nickel, 1.0.

2.—Copper, 35.0; zinc, 56.5; nickel, 8.5.

3.—German silver, 5; zinc, 4.

1 and 2 are quite similar in composition, and have correspondingly similar properties; in 3, German silver, that is, a compound of copper, zinc, and nickel, is used directly, and in preparing this solder it is necessary to know the exact composition of the alloy, or to try the solder in small

quantities, in order to judge of the correct amount of zinc to be added. It may be assumed that the proportions are correct, when the metallic mixture is lustrous, and brittle enough to allow of pulverizing when hot, and when it will become fluid in contact with a red-hot soldering iron.

Hard German Silver Solders (Steel Solders).—1.—Copper, 35; zinc, 56.5; nickel, 9.5.

2.—Copper, 38; zinc, 50; nickel, 12.

1 requires a very hot flame for melting, and 2 can usually be melted only by applying bellows to the flame.

Silver Solders

The solders which contain silver are very strong and tenacious, and are used not only to solder silver, but also for other metals, in cases where the objects to be soldered require great power of resistance. Two principal kinds of silver solder are distinguished, hard and soft, the former consisting of silver and copper, with sometimes a little zinc, and the latter containing, besides the metals just mentioned, a small amount of tin.

Hard Silver Solder.—According to the purpose for which this is intended, different compositions are used varying in fusibility. Silver workers use different solders for alloys of varying degrees of fineness, and the same ones are not always employed for resoldering as for the first soldering.

Very Hard (for Fine Silver Articles).—Copper, 1; silver, 4.

Hard.—1.—Copper, 1; silver, 20; brass, 9.

2.—Copper, 2; silver, 28; brass, 10.

Soft.—1.—Silver, 2; brass, 1.

2.—Silver, 3; copper, 2; zinc, 1.

3.—Silver, 10; brass, 10; tin, 1.

4.—These solders serve principally for completing the soldering of silver articles done with hard solder, by retouching imperfect places. Some silver workers use for this purpose copper and silver alloys mixed with zinc, as for example, the following: Copper, 4; silver, 12; zinc, 1; or:

5.—Silver, 5; brass, 6; zinc, 2. The latter is readily fusible, but also rather brittle, and is frequently used for soldering ordinary silverware.

Solders for Iron, Steel, Cast Iron, and Copper.—1.—Silver, 10; brass, 10.

2.—Silver, 20; copper, 30; zinc, 10.

3.—Silver, 30; copper, 10; tin, 0.5.

Soft Silver Solders.—Silver, 60; brass, 60; zinc, 5.

In the case of solders which are prepared with brass, care should be taken that neither of the metals in the composition contains iron, as it has been found by experience that the presence of a very trifling amount of this is sufficient to change the character of the alloy materially, making it brittle.

Silver solders are used in the form of fine filings or wire, the latter method of preparing it being especially adapted to the tenacious and ductile nature of the alloy.

In the large manufactories for silver ware it has become the custom in recent years to use the same alloy for soldering as that of which the silver article is made. It is used in the form of filings, and melted into the seams so that the object and the solder are really homogeneous.

Gold Solders

Gold, both pure and various alloyed, is used to a considerable extent in soldering, but on account of its expensiveness it is limited to articles made of gold or platinum, or the most delicate small steel objects.

Gold objects are of different colors, according to the kind and proportion of the other metals used. There are yellow, red, white, and green gold alloys. The color of the special alloy should of course be in harmony with the color of the object to be soldered, in order that the seams may be as inconspicuous as possible.

The fusibility of gold alloys varies as much as their color, and is lowered as the amount of gold in the alloy increases. Harder solders should therefore be used for objects of fine gold than for a poorer quality.

Gold solders are made from gold and silver, gold and copper, and still more frequently from a mixture of all three of these metals; in some cases zinc is added to make the solder softer. But this must not be done if the soldered articles are to be colored, as the zinc alloy will turn black in coloring. For objects which are to be wholly or partially enameled, the solders made of gold and silver, or of gold, silver, and copper, are the only ones used, and these are called "enamel solders."

Hard Gold Solder.—Gold 750-1000 fine (18 carat), 9; silver, 2; copper, 1.

This is used for the finest gold articles.

Soft Gold Solder.—Gold, 750-1000 fine (18 carat), 12; silver, 7; copper, 3.

This is likewise used for fine gold, but is much more fusible than the one first given.

Gold Solder for Articles 583-1000 Fine (14 Carat).—Gold, 583-1000 fine (14 carat), 3; silver, 2; copper, 1.

2.—Gold, 583-1000 fine (14 carat), 4; silver, 1; copper, 1.

Gold Solder for Ordinary Gold Ware Less than 583-1000 (14 Carat) Fine.—1.—Fine gold, 1; silver 2; copper, 1.

2.—Fine gold, 1; copper or silver, 1.

Soft Gold Solder.—1.—Fine gold, 11.94; silver, 54.74; copper, 28.17; zinc, 5.01.

2.—Gold, 583-1000 fine (14 carat), 10; silver, 5; zinc, 1.

The degree of fusibility of an enamel must decide the question as to which one of these compositions to use. If it is very hard, the first solder is the proper one, as otherwise the seams would become so hot during the process of melting the enamel that the solder itself would melt. For ordinary gold ware soft enamels are generally used, and in this case the softer solder can be employed. It is easily melted with the common soldering pipe; the harder can also be melted in the same way, but the use of a special apparatus makes the process much easier and quicker.

Aluminum Solders

Since the discovery of aluminum and its production in considerable quantities, it has become a common material in the manufacture of various artistic objects. One of the greatest difficulties, however, in the past has been that there was no perfect solder for aluminum, and various alloys were used which gave unsatisfactory results. This difficulty has now been overcome, and it is possible to solder the metal so perfectly that in tests which have been made the metal itself broke before the solder gave way.

The French manufacturers use five kinds of solders for aluminum, all consisting of zinc, copper and aluminum in different proportions. These are given below. Parts by weight.

1.—Zinc, 80; copper, 8; aluminum, 12.
2.—Zinc, 85; copper, 6; aluminum, 9.
3.—Zinc, 88; copper, 5; aluminum, 7.
4.—Zinc, 90; copper, 4; aluminum, 6.
5.—Zinc, 94; copper, 2; aluminum, 4.

There are also other compositions besides these. Bourbouze recommends, for objects which are to be further manipulated or worked on after soldering, a mixture of 45 parts of tin and 10 of aluminum.

6.—Frischmuth gives the following alloys for solders:

a.—Silver, 10; copper, 10; aluminum, 20; tin, 60; zinc, 30.

b.—Tin, 95 to 99; bismuth, 5 to 8.

The composition b (an ordinary soft solder) is adapted for soldering aluminum by means of the common soldering iron.

In preparing aluminum solders, the alloy of copper and aluminum is always made first and the zinc added. First of all the copper is melted, and the aluminum put in gradually, usually in three or four portions. The two metals are of very different density, and the mixture should be stirred with an iron rod, to unite them as far as possible. Immediately after adding the last portion of the aluminum, the zinc is put in, and at the same time some fat or rosin is thrown into the kettle, the whole is quickly stirred, the kettle removed from the fire, and the alloy poured into iron molds which have been rubbed with coal oil or benzine. The whole work must be done as quickly as possible after the addition of the zinc, or the solder will not remain in a suitable condition.

The zinc used should contain no iron, as a very small amount of the latter would materially affect the fusibility and durability of the solder. The purpose of the fat or rosin is to prevent the oxidation of the zinc, and, as before observed, the work must proceed as rapidly as possible from this moment, as the temperature of the mass is so high that if it were left long in fusion much of the zinc would evaporate.

On account of its resistance to chemical influences, aluminum solder is frequently used by dentists to unite the metallic parts of artificial teeth, but alloys for this purpose must not contain copper except in very small quantities, as this metal is easily attacked by acids.

Platinum and Aluminum Solder.—Gold, 30; platinum, 1; silver, 20; aluminum, 100.

Aluminum and Gold Solder.—Gold, 50; silver, 10; copper, 10; aluminum, 20.

SOLDERS FOR SPECIAL PURPOSES

Brass

For soldering with sheet brass with a copper, use a solder made of 2 parts tin, 1 part lead, by weight; melt, mix and pour in small bars. For flux dissolve zinc in muriatic acid until no more will dissolve, add about one-tenth its bulk of sal ammoniac and dilute with quarter its bulk of water. Wet the surfaces to be soldered with this solution, using a piece of wood or copper wire for this purpose. Then, by rubbing the surfaces with the tinned point of the copper, a coating of tin will be imparted. Put both surfaces thus prepared together and heat by applying the copper and a little solder to the outside of the seam. The copper should be well tinned on the point, which may be done by heating the copper hot enough to freely melt pure tin. Rub a piece of

sal ammoniac on a brick, then rub the copper point on the brick, with tin or solder in contact with the point. The tinning of the copper point is essential for soldering.

Britannia Ware, White Solder

Tin, 50 lb.; copper, 4 lb.; lead, 2 lb.; antimony, 4 lb.

Glaziers' Solder

Lead, 5 parts; tin, 1 2-3 parts. This melts at 500° F.

Iron

To solder cast iron, clean the place to be soldered well, then brush it with a brass wire brush until the iron becomes yellow. It will be found that the solder can now be applied without any trouble.

Nickel, Solders for

For fine or high-grade nickel: 3 parts of yellow brass, 1 part of sterling silver. For low-grade nickel: 15 parts of yellow brass, 5 parts of sterling silver, 4 parts of zinc (pure or plate zinc). Melt the brass and silver with borax for a flux and add the zinc in small pieces, stir with an iron rod, pour into a slab mold and cool slowly, when it can be rolled thin for cutting.

Pewter and Britannia Metal

1.—Tin, 10 parts; lead, 5 parts; bismuth, 1 to 3 parts.

2.—Take tin, 3 parts; lead, 1½ parts; bismuth, 1½ parts.

3.—Solder for Tin or Pewter.—Tin, 2 parts; lead, 1 part; bismuth, 1 part.

Platinum Soldered to Gold

To make platinum adhere firmly to gold by soldering it is necessary that a small quantity of fine or 18-carat gold shall be sweated into the surface of the platinum at nearly a white heat, so that the gold shall soak into the face of the platinum; ordinary solder will then adhere firmly to the face obtained in this manner. Hard solder acts by partially fusing and combining with the surfaces to be joined, and platinum alone will not fuse or combine with any solder at a temperature anything like the fusing point of ordinary gold solder.

Steel

Steel Soldering.—This recipe, according to the Werkmeister Zeitung, is useful for cases when the steel is not to be soldered at an elevation of temperature to the bright red. Dissolve scraps of cast steel in as small a quantity as possible of nitric acid, add finely pulverized borax and stir vigorously until a fluid paste is formed, then dilute by means of sal ammoniac and put in a bottle. When soldering is to be done, apply a thin layer of the solution to the two parts to be soldered, and when these have been carried to ordinary redness, and the mass is consequently plastic, beat lightly on the anvil with a flat hammer.

Steel Wire, To Solder.—Mix 1 lb. lactic acid, 1 lb. glycerine and 8 lb. water, so as to have a clear solution. This is non-corrosive, but does not work as quickly as the ordinary soldering acid.

Steel Joints, Solder for.—Brass, 3 parts; copper, 1½ parts; silver, 28½ parts.

Steel, Hard Soldering.—Solder will not run on iron quite so well as on silver or brass. See that the steel is clean and bright, use the borax as a thick paste and the operation must be concluded quickly.

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